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PLUG-AND-USE RENOVATION WITH ADAPTABLE LIGHTWEIGHT SYSTEMS

D2.4

Heating and cooling technology selection

Version: 1.0

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Terms, definitions and abbreviated terms

AHU	Air Handling Unit
COP	Coefficient of Performance
DHW	Domestic Hot Water
eAHC	External Air Handling unit with Heating and Cooling
EER	Energy Efficiency Rate
ELA	Equivalent Leakage Area
ETICS	External Thermal Insulation
FCU	Fan Coil Unit
eWHC	External Wall Heating and Cooling
HVAC	Heating, ventilation & Air conditioning
HP	Heat Pump
nZEB	Near Zero Energy Building
PnU	Plug and Use
RES	Renewable Energy Sources

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Executive Summary

PLURAL targets to design, validate and demonstrate a palette of versatile, adaptable, scalable, off-site prefabricated plug and play hybrid facades integrating active and passive systems and accounting for user needs (named “Plug-and-Use” - PnU - kits). For this purpose, PLURAL focuses on three main pillars:

- Assessing different core systems, which couple heating-cooling, ventilation, heat harvesting systems with smart windows, 3D printing, low carbon footprint coating materials and smart control systems towards nZEB status for different European climates and different residential building typologies (<60 kWh/m2 per year of buildings’ total primary energy consumption and >50 kWh/m2 per year of on-site renewable energy generation).
- Utilizing a BIM based management platform coupled with Decision Support Tool (DST) in order to optimize the component selection and integration, as well as to optimize the PnU kit design, production and manufacturing speed, cost manufacturing and installation (≥ 50% reduction in the time required for deep renovation of e.g. multi-family blocks, 58% reduction in renovation costs through off-site prefabrication lean manufacturing and construction, interactively supported by the BIM based platform and DST)
- Demonstrating the applicability of the PnU kits by implementing the solutions in three real and three virtual residential buildings in order to evaluate the renovation time and cost reduction, the PnU kits performance, carbon savings and users’ comfort.

WP2 deals with the design and the technologies integrated in the PnU kits. The current deliverable D2.4 is the result of work performed under Task 2.4 that focuses on the heating and cooling technologies incorporated in the PnU kits that are going to be installed in the demonstration buildings. It gets basic data and information from previous Tasks 2.1 & 2.2 while it also uses the preliminary renovation design of Task 7.1 and Task 2.6 in order to acquire all input needed for selecting the heating and cooling systems for the real and virtual demo buildings renovation.
Deliverable D2.4 is public, aiming to provide overview of the methodology followed in PLURAL for the selection of the heating and cooling technologies incorporated in the PnU kits.

Achievements

The main achievement of the task is the final selection of all heating (and cooling wherever applicable) systems along with all other auxiliary and control systems that are needed for their operation. The selection mostly refers to the real demonstration cases in Voula, Greece and in Kasava, Czech Republic. For the demonstration building in Terrassa, Spain the renovation includes the installation of innovative ventilation units with active heat recovery systems while the main heating and cooling functions will be done by the existing systems.
To reach the aforementioned selections, the type of heating (and cooling) technology had to be decided. For this purpose, the buildings were analysed in terms of heating and cooling loads, DHW demand and profile of use. After these, selection and sizing of the main systems was made. Finally, the design of the complete heating (and cooling) system was made including all the necessary components and supported by relevant simulations and drawings. The selection of equipment reached almost the final level of defining specific types and quantities depending on the case.

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Introduction

Deliverable D2.4 focuses on selecting the heating and cooling technologies that are suitable for the PnU kits of the PLURAL project both in terms of the prefabricated panels approach and the specific demonstration buildings' characteristics and specifications. The three basic PnU kits which will be deployed in the three demonstration buildings are:

- The **"SmartWall"**, a multifunctional prefabricated wall panel
- The **"eWHC"**, an external prefabricated Wall Heating and Cooling module panel
- The **"eAHC"**, a prefabricated module with air handling unit with Advanced Heat/Cool recovery system

The three different PnU kits set themselves some boundaries regarding the compatibility with heating and cooling systems. SmartWall's diversity allows the incorporation of most types of terminal systems within its structure while the eWHC and the eAHC include by definition a specific terminal system for heating and cooling. The eWHC integrates a Wall Heating system with pipes while the eAHC integrates an Air Handling Unit (AHU) with heating and cooling. In this task, all necessary actions were performed in order to fulfil its objective.

Objectives

The Task has one main objective which is the final selection of the heating and cooling systems that will match the PnU renovation plan of real demonstration buildings of PLURAL project. This objective is realized by fulfilling three basic steps:

1. Specifying the type of system to be used in the demonstration buildings
2. Sizing of the systems based on the heating and cooling loads
3. Final design of the system including the specification of all equipment needed

Relation with other WPs and Tasks

In the previous tasks of WP2 the architectural and structural design of the PnU was described (Task 2.1) and all the integrated technologies defined (Task 2.2). Tasks of WP1 with the regulations and requirements (Task 1.2 and Task 1.6) along with Task 7.1 survey and preliminary renovation design of the renovation buildings, provided crucial information for the final selection of the systems to be possible. The outcome and results of this task will firstly provide input to task 2.6 for the final design of the PnU kits and next to those of WP7 that deal with the actual systems that are going to be installed in the demonstrators and with all of its specifications for simulation and validation purposes.

Report Structure

In the first chapter of the current report, a more general review of typical and more innovative heating and cooling technologies is presented and the compatible technologies with each of the PnU solutions are determined. In the second chapter the demo buildings are examined in terms of thermal and cooling loads that will determine the sizing of the respective systems. Chapter 3 finalizes the heating and cooling specific systems selection for all demo buildings. In Chapter 4 the final and complete heating and cooling solutions for each demo are described and supported with relative drawings, calculations and simulations results. In Chapter 5 conclusions are drawn and in Chapter 6 there are the Annex with some more technical details about the methods of the sizing and heating and cooling loads as well as technical specifications of the systems.

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1 PLURAL heating and cooling technologies review - evaluation and PnU compatibility

1.1 Heating & Cooling technologies review

A variety of heating and cooling technologies for providing comfortable living conditions can be used in buildings. Some technologies tend to be more suitable for residential buildings and others for other types of building uses. Heating and cooling systems are consisted of three basic parts. The heating or cooling plant or unit which is the system that generates or extracts heat utilizing a heat / energy source, the heating or cooling distribution network that utilizes a medium to transfer heat to the third part which is the terminal system that is responsible for delivering or removing heat to or from the actual living space.

A general review of the most common heating and cooling technology is given in the Table 1.1 as a starting point for the selection of the appropriate technologies for the PnU solutions and the demo buildings of PLURAL project. Technologies are described by giving the main advantages and disadvantages and by describing the usual type of distribution network and the terminal units that are compatible with as well as possible combinations with renewable energy sources (RES).

TABLE 1.1: HEATING & COOLING TECHNOLOGIES FOR BUILDINGS CLASSIFIED BASED ON HEAT SOURCE UNIT

Heating and/or Cooling Technology	Advantages	Disadvantages	Network	Compatible Terminal systems or AHUs	RES combination
Gas boiler (condensing)	▪ Cheap ▪ Compact size ▪ DHW compatible	▪ Burns natural gas which is a fossil fuel – CO_2 emissions ▪ Only heating ▪ Extra piping and safety measures ▪ Available network needed ▪ Chimney needed	▪ Water piping, circulator pump	▪ Radiators/convectors ▪ Fan-Coils ▪ Underfloor/surface heating ▪ AHU	▪ Has to be combined with a large solar collector field in order to be nZEB acceptable
Biomass boiler	▪ Burns biomass which is considered CO_2 neutral	▪ Biomass supply / storage ▪ Even neutral still emits gases – local air pollution	▪ Water piping, circulator pump	▪ Radiators/convectors ▪ Fan-Coils ▪ Underfloor/surface heating ▪ AHU	

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		▪ Frequent maintenance ▪ Low efficiency ▪ Only heating			
Chiller	▪ Consumes electricity	▪ Only cooling	▪ Water piping, circulator pump	▪ AHU ▪ Fan-Coils	▪ PV system
Air to water heat pump	▪ Both heating and cooling ▪ High efficiency for low-medium temperature applications ▪ Compact size ▪ Consumes electricity ▪ Zero emissions on-site ▪ DHW compatible	▪ Capital cost intensive ▪ Not efficient for high temperature applications	▪ Water piping, circulator pump	*Heating only:* ▪ Radiators/convectors *Heating & Cooling:* ▪ Fan-Coils ▪ Underfloor/surface heating (limited cooling) ▪ AHU	▪ PV system ▪ And /or Solar thermal system
Ground source heat pump	▪ Both heating and cooling ▪ Very high efficiency for low-medium temperature applications ▪ Consumes electricity ▪ Zero emissions on-site ▪ DHW compatible	▪ Requires a large land area for the ground heat exchanger ▪ Very high capital cost of the ground boreholes	▪ Water piping, circulator pump	*Heating only:* ▪ Radiators/convectors *Heating & Cooling:* ▪ Fan-Coils ▪ Underfloor/surface heating (limited cooling) ▪ AHU	▪ PV system ▪ And /or Solar thermal system
Air to air heat pump (direct expansion local units: split, multi split units and VRV)	▪ Both heating and cooling ▪ High efficiencies ▪ Decentralized systems ▪ Consumes electricity ▪ Zero emissions on-site	▪ Only air heating systems, comfort, room stratification, air velocity, range issues.	▪ Small refrigerant piping ▪ Ducts	▪ Split type internal units	PV system
Solar thermal collectors	▪ Renewable energy ▪ DHW compatible	▪ Large area required to cover demand ▪ Specific angle for winter optimization energy yield	▪ Water piping, circulator pump	▪ Radiators/convectors ▪ Fan-Coils ▪ Underfloor/surface heating	

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		▪ Big storage needed ▪ Only heating ▪ Capital Cost intensive			
(micro)CHP (Combined Heat & Power)	▪ Both heat and power (electricity) generation	▪ Capital Cost intensive ▪ Burns natural gas which is a fossil fuel – CO_2 emissions ▪ Only heating ▪ Not ideal for decentralized small scale applications	▪ Water piping, circulator pump	▪ Radiators/convectors ▪ Fan-Coils ▪ Underfloor/surface heating	
Electrical resistance systems	▪ Compact ▪ No outdoor unit, piping required	▪ Only heating ▪ Low efficiency – joule effect (Consumes 1 kW of electricity to deliver 1kW of heat)	▪ No piping	▪ Electrical Radiators/convectors ▪ Electrical underfloor heating ▪ Infrared radiant heating ▪ AHU	PV system

The technologies presented in the table above range from mature technologies (boilers) to technologies that are still evolving and improving (heat pumps). The classification was made based on the type of heating and or cooling unit of the technologies and then the compatible network type and terminal system were described. Other systems may have as a heat source one of the above main systems and have a more innovative terminal system type (electric foils, capillary system, water piping system embedded in slabs/walls etc.)

In D2.2 an extensive review of heating technologies was presented based also on the heating and/or cooling medium and on the type of terminal unit that is utilized. In this report one of the objectives is to select and justify the heat source type, as the heat transfer medium and the terminal units of each case have been defined.

1.2 PLURAL demonstration buildings preliminary heat source selection

The PnU solutions of the PLURAL project can support certain terminal systems which limit the selection of the ideal heating and/or cooling source. The PnU developers and the building owners have selected the terminal systems for heating and cooling for each specific renovation plan with the respective PnU

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kit for each demonstration building. However, the PnU kits may also support other types of terminal system depending also on the respective application. In the next sections a preliminary heating and cooling source type selection will be justified for all the demonstration buildings of the PLURAL project, both real and virtual.

The selection will be made based on the following five basic criteria:

1. Compatibility with already selected terminal systems of the demonstration buildings renovation plan
2. Fuel/energy carrier availability
3. Minimization of Green House Gas emissions
4. Renewable Energy Source compatibility and combination
5. Technoeconomic feasibility

First criterion is already explained while the second one has to do with the type of fuel the heating system will use. Apart from electricity, which is available in all buildings, other type of fuels could be considered but their availability is not ensured (natural gas grid availability, biomass etc.). The third one has to do with minimizing the environmental impact by using the most eco-friendly technologies. The fourth examines if the respective system will be able to use energy from renewable energy sources, either on-site or not. The final one will justify the feasibility of the selected system considering any limitations that may occur from the specific characteristics of the demonstration buildings or from the designed PnU renovation plan.

1.2.1 Greek demonstration building in VVV – SmartWall renovation

1.2.1.1 PnU renovation overview

As it has been described in previous deliverables of the project (D7.1 – "Buildings' survey and preliminary design and D2.2 – Façade panel technologies selection), the renovation scheme of the Greek demonstration case, includes the installation of SmartWall PnU kits in the two apartments that consist of the first floor of the demonstration building of the municipality of VVV.

SmartWall is a versatile prefabricated panel developed by AMS that can be installed externally or internally to an existing building façade. It consists of a metal or other material frame, insulation materials, gypsum/cement boards for covering and various types of coatings for finishing and rendering. Depending on the position and the existing wall that is going to be attached, the SmartWall may include a window, or a door with a shutter or blind. SmartWall also can feature a big variety of electromechanical equipment to cover any demand of the building renovated. This includes space in the panel for a heating/cooling unit that can be diversified depending on the application or the renovation scheme.

Integrated photovoltaic system can also be attached on the external side of the SmartWall powering all its functions that require electricity.

FIGURE 1.1: EXAMPLE OF SMARTWALL PANELS: INTERIOR SURFACE WITH THE FAN COIL UNIT LOCATION AND EXTERIOR SURFACE WITH A WINDOW AND AN INTEGRATED PV PANEL

For the demonstration renovation of the two apartments of the residential building at VVV it is planned (as explained in next section 1.2.1.2) that the SmartWalls will include fan – coil units (FCU) in order to cover all the heating and cooling needs. The heating and cooling load calculation for each separate space will determine how many FCUs are needed. Since the renovation plan includes several SmartWall panels per room as shown in the Figure 1.1 above, it is feasible to select how many of them will integrate an FCU based on the heating and cooling loads.

The initial design of the SmartWall included also a PV integration on each panel. However, due the specific architectural characteristics of the demonstration buildings it was not possible for integrated PV panels to be installed. Instead, they will be installed on the flat roof of the building after the Municipality of VVV gave the permission to do so. One separate system per apartment will be installed on the roof with the ideal inclination and orientation for maximizing energy yield.

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FIGURE 1.2: INTEGRATION AND POSITIONING OF SMARTWALL PANELS IN GREEK DEMO SITE

1.2.1.2 Heating & Cooling system type selection

The basic requirement of VVV Municipality for the Greek demonstration building was the use of a system which can both provide heating and cooling functions, and that each of the apartments that will be refurbished, to be autonomous in terms of energy consumption. These specific demands, by their nature, are excluding a wide range of devices such as radiators, any type of heating panels, IR panels, etc.; hence, the choice for the heating – cooling devices was limited between fan-coils, air ducting system and air-conditioning.

By following the methodology and all the limitations and restrictions described in Deliverables 2.1 and 2.2, it was concluded that:

- the use of an air ducting system was not favourable as per VVV Municipality request, because of the complexity of the system in terms of apartment's energy autonomy, as well as the number of installations required in the roof of the building and the external (on the façade walls) routing of the ducting system;
- the energy consumption of any air-conditioning type e.g. split units, cassettes, VRV's etc., was higher than a combination of fan-coils and heat pump, and
- additionally, the use of solar collectors for domestic hot water supply combined with a heat pump as a backup system, could ameliorate the efficiency of the whole system and further reduce the energy consumptions (three-way energy deflection system).

Therefore, to maintain the autonomous energy consumption status of each apartment, it was decided that each apartment should have its own heating – cooling circuit / pipework as well as its own heating/cooling unit which will feed with hot/cold water a number of fan coil units.

An FCU utilizes water as the heat transfer medium and combines a pipe coil where the water flows and a fan that blows air which is heated or cooled from the coil before it goes into the conditioned room. This fact leads to the primary selection of heating system that can deliver hot or cold water to the FCUs. An additional parameter is the temperature of the water that must be delivered in order to match the FCU typical inlet water temperature to ensure their nominal heating or cooling capacities. Fan coils are used to be fed with low to medium temperature for heating which means 45 to 55 ^{o}C. For cooling they usually need a 7 to 12 ^{o}C water to provide their nominal capacity values. Considering these characteristics of the FCUs the possible systems for heating and cooling are the following:

a) Conventional boilers

Typical heating systems like boilers are used to deliver hot water to heating systems. Condensing oil or gas boilers have reached high efficiencies but they still have some significant drawbacks. They use as a heat source a fossil fuel. They burn oil, natural gas or LPG that produces CO_2 emissions which cannot be covered by any renewable system. Boilers provide only heating which means that an extra system would be needed for cooling and in the case of FCUs a conventional chiller or a heat pump would be necessary for providing cold water in the summer. Apart from this a natural gas grid should be available or enough space for a fuel tank (oil or LPG).

b) Biomass boilers

Instead of a gas boiler a biomass boiler could supply hot water by burning wood pellets or other type of biomass. Biomass is considered as renewable energy source. Apart from providing only heating, supplying of the biomass is a drawback as it has to be ordered and delivered on time in order not to jeopardize comfort, while it also needs a person to handle the feeding of the boiler. In addition, burning of biomass in urban areas is in general not a good practice as it adds various emissions to the urban air, deteriorating local air quality.

c) Air to water heat pump:

With such a system both heating and cooling is possible as it can transfer heat to the water of a closed circuit or remove heat from it by reversing its cycle. Ambient air is used as the heat source or heat sink which means that an external location for installation is necessary. The heat pump consumes electricity and its efficiency depends on both the ambient air temperature and the demanded water temperature. Typical efficiencies of a heat pump for heating is higher than 3.5 (COP) for 7 ^{o}C ambient air temperature and 45^{o}C water temperature. This means that with 1kW of electricity the heat pump provides 3.5 kW of heat. For cooling, typical efficiency is around 4 (EER) for 35 ^{o}C ambient air temperature and 12^{o}C water temperature.

An air to water heat pump is either a single device (monobloc type) or a two separate parts device (split type) which are connected with refrigerant piping. The monobloc type has to be installed externally in order to utilize ambient air. The split type consists of the internal and the external unit which are installed respectively. Monobloc is usually selected where no internal space is available.

As all systems that consume electricity a heat pump can be combined ideally with a PV system to cover part or all of its consumption and contribute to nZEB level renovation.

d) Water to water heat pump /ground source heat pump:

A more efficient system could be the ground source heat pump which exploits the higher temperature of the ground (or a water natural reservoir) in comparison with ambient air (for heating in the winter). However, such a system is quite expensive due to the drilling of the ground boreholes and also requires a large land area. For these reasons it is usually ideal for large buildings and installations with sufficient free land space in the surroundings area. Furthermore, due to its high installation cost, a technoeconomic study should prove the cost effectiveness of such a system.

e) Solar thermal systems

Finally, a solar thermal system using solar collectors to provide directly the heating system with hot water could be an alternative. Apart from being only a heating solution, the sizing of such a system for space heating is more complex and requires a large area of solar collectors and a big storage tank in order to be reliable. Solar thermal systems usually support and not totally cover heating loads for space heating. However solar thermal systems only for DHW are smaller and useful all year long and they will be considered for the Voula demonstration building in Task 2.5.

Conclusion and selection of type of system

To conclude, an air to water heat pump seems to be the most ideal to be combined with the SmartWall renovation scheme of the Greek demonstration building having a lot of advantages in comparison with other alternatives.

Compared to a gas or a biomass boiler, it is obvious that an air to water heat pump is more versatile having the ability of providing both heating and cooling. A heat pump is also consuming electricity which makes it ideal for combining it with the PV system that will compensate a part of the electricity consumption. Another reason for selecting a heat pump is the terminal systems selected for the SmartWall renovation. Fan coils are usually combined with medium temperature water which means around 45 to 55 ^{o}C for heating mode. At these range of temperature, a typical air to water heat pump usually runs very efficiently, depending also on the ambient temperature. What is more, a modern heat pump has all features of smart control and automations in order to fit with the overall control of each apartment systems and it can also be used for DHW preparation.

Compared to a water to water or a ground source heat pump an air to water has lower efficiencies both in heating and cooling mode. However, as explained previously a water to water heat pump needs either a water reservoir nearby the building or boreholes drilled to the ground for piping to run into. Such an installation requires a lot of space and is very capital intensive. The demonstration building in VVV Municipality does not have that much of surrounding free land. Even if it did, the benefit for having a higher temperature sink than the ambient air would not be very high. Winters in the area of VVV Municipality which is located in the southern suburbs of Athens are relatively mild and short. Proximity to the sea is also one of the reasons for this.

Consequently, the system for heating and cooling that is selected for the SmartWall renovation of the demonstration building of VVV is an air to water heat pump that will be combined with fan coils and will provide both heating and cooling. More specifically each apartment's heating /cooling system it will be consisting of:

- a mono-block type heat pump by DAIKIN,
- slim type FWXM10ATV3[1] fan-coils by DAIKIN capable to be fitted internally in the SmartWall, @ 576 mm (h), 725 mm (l) 126 mm (w) and
- two wall mounted fan coil units by DAIKIN, which will be installed in the kitchen areas of the apartments due to the limitation of space.

A mono-block type heat pump is a heat pump that contains all its parts in one piece and is installed at an external location and it was preferred for the Greek demonstration building as internal space for equipment installation is very limited.

In addition, it was decided that the heat pump solution will support the production of Domestic Hot Water (DHW) for the two apartments, when solar energy is not sufficient to produce the required amounts of DHW (DHW will be provided by the use of selective flat solar collectors which will be described in *D2.5 "Report with design and operational features of toolbox"*).

More details about the specific selection will follow in Chapter 3 after the calculation of the heating and cooling loads (Chapter 2).

[1] https://www.daikin.eu/content/dam/document-library/catalogues/heat/heat-emitters/fwxv-atv3/Daikin%20Altherma%20HPC_Product%20catalogue_ECPEN21-793_English.pdf

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1.2.2 Czech demonstration building in Kasava – eWHC renovation

1.2.2.1 PnU renovation overview

The PLURAL renovation scheme of the demonstration case in Czech Republic is going to be deployed in a two-floor residential building that will be consisted of two independent apartments after the renovation. The PnU kit that is going to be applied to this building is the eWHC which is consisted of a wooden frame and utilizes a piping network incorporated inside a layer of the prefabricated panel that will be attached on all the existing walls of the building. The existing walls will be thermally activated by the piping system and they will transfer the heat from the interior of the building. The PnU kits will also have thermal insulation integrated on the outer part of the panel to prevent heat losses as well as high performance windows. Apart from the walls, PnU kits will be also deployed on the roof without a heating system but with integrated PV panels. Architectural design of the renovation also includes the reconstruction of some spaces of the first floor by redesigning the roof and some walls as well, in order to optimize the living spaces.

FIGURE 1.3: DEMONSTRATION BUILDING IN KASAVA AT THE PRE-RENOVATION STATE (LEFT) AND A SCHEMATIC OF THE PANELS OF THE NORTH FAÇADE OF THE BUILDING SHOWING THE HEATING MEANDERS (WATER PIPING)

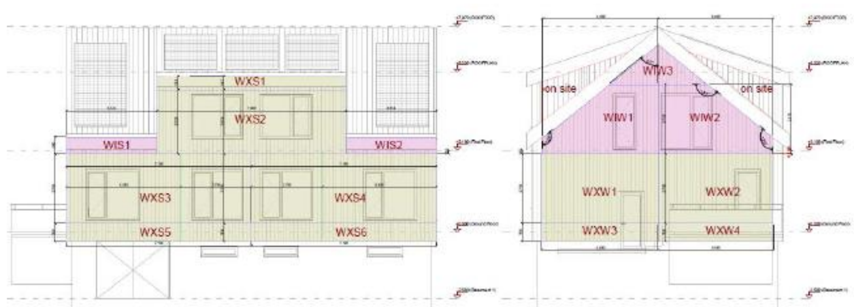

FIGURE 1.4: FAÇADE DRAWINGS OF THE KASAVA BUILDING WITH THE EWHC MODULES

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The selection of the heating technology and the type of heat source is strongly affected by the PnU kits. The eWHC system is a water piping system which means that the medium delivering heat to the indoor spaces is predefined. The water piping inside the prefabricated panels are actually playing the role of both the distribution and the terminal system of the heating system as it is depicted in the following figure.

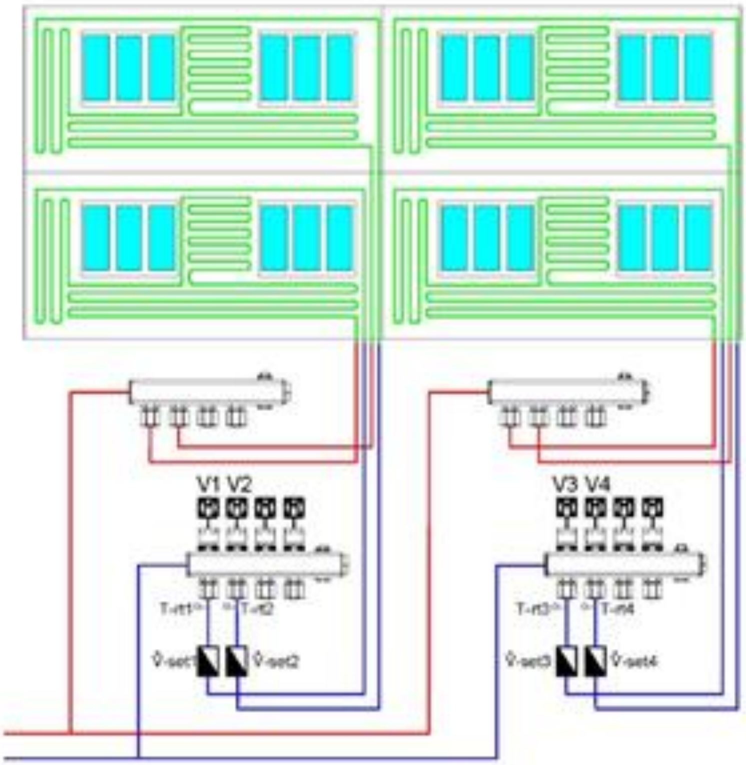

FIGURE 1.5: OUTLINE OF THE SPACE HEAT DISTRIBUTION OF THE EWHC WITH FOUR FAÇADE MODULES, FOUR HEATING MEANDERS AND TWO BRANCHES OF THE DISTRIBUTION LINE WITH TWO PAIRS OF DISTRIBUTORS ACCORDINGLY

1.2.2.2 Heating system type selection

Considering the fact that the terminal systems utilize water for delivering heat, the heat generation system should also have as an output water. Another fact is that due to the nature of terminal system the temperature level required is in the range of low temperature heating levels, meaning 30 – 40 °C. This temperature range is also used for underfloor heating and other high inertia systems. In the following paragraphs all possible systems are examined briefly considering advantages and disadvantages. The case of heat source selection is similar with the Greek demonstration building. The difference is that the desired water temperature is lower.

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a. Boilers (Conventional & Biomass)

Typical boilers like Condensing oil or gas boilers are the most common system used for space heating. However, they burn oil, natural gas or LPG that produces CO_2 emissions which cannot be covered by any renewable system. Apart from this a natural gas grid should be available or enough space for a fuel tank for oil or LPG. Reaching nZEB levels cannot be done using a conventional boiler unless its fuelled with biomass. Instead of a gas boiler a biomass boiler could supply hot water by burning wood pellets or other type of biomass. Biomass is considered as renewable energy source. Biomass feeding and logistics is a drawback.

b. Air to water heat pump:

A Heat pump is an ideal system for cases with low temperature heating as it runs with high performance coefficients. The efficiency, however, depends also on the ambient air temperature which is very low during winter in Czech Republic. Typical efficiencies of a heat pump for heating is around 3 (COP) for -7 ^oC ambient air temperature and 35^oC water temperature. This means that with 1kW of electricity the heat pump provides 3.0 kW of heat.

An air to water heat pump is either a single device (monobloc type) or a two separate parts device (split type) which are connected with refrigerant piping. The monobloc type has to be installed externally in order to utilize ambient air. The split type consists of the internal and the external unit which are installed respectively. Monobloc is usually selected where no internal space is available.

Compatibility with a PV system to cover part or all of its consumption and contribute to nZEB level renovation is also a significant advantage.

c. Water to water heat pump /ground source heat pump:

A ground source heat pump would be more efficient exploiting the higher temperature of the ground in comparison with ambient air especially to a country like Czech Republic with below zero temperatures in Winter. However, such a system is quite expensive due to the drilling of the ground boreholes and also requires a large land area. For these reasons it is usually ideal for large buildings and installations with sufficient free land space in the surroundings area. Furthermore, due to its high installation cost, a techno-economic study should prove the cost effectiveness of such a system. Specifically, for the demonstration building in Kasava, there is not enough land area around the building, so there is no point evaluating such a solution.

d. Solar thermal systems

A solar thermal system using solar collectors for partial covering the heating demand could be an alternative renewable source for reducing heating costs. Such a system would require a quite large area of collectors for achieving a substantial solar energy cover. What is more, the design of the PnU kit for the roofs integrates PV panels for electricity generation which it can be consumed onsite or directed to the grid and also contribute to the nZEB level requirement.

Conclusion and selection of system type

Considering all the above, the selection of an air to water heat pump is also the case for the demonstration building of Kasava. In comparison with boiler systems, it has the advantage of combining it with a PV system and not emitting any gases on site. Installation space required is not a barrier as there is enough space in the Kasava building both outdoors and indoors. Solar thermal or ground source heating systems are not considered due to techno-economic feasibility reasons. Low ambient winter temperature that affects a heat pump's performance is kind of a drawback but is compensated by the low water heating temperature due to the nature of the terminal system (wall piping - eWHC). What is left to be decided is the number and the specific model(s) of the air to water heat pump.

1.2.3 Spanish demonstration building in Terrassa – eAHC renovation

1.2.3.1 PnU renovation overview

The Spanish demonstration building in Terrassa is a multifamily residential building that is consisted of three floors. The building was never used and abandoned after its construction. Now it is under AHC property and is undergoing a two-phase refurbishment. The first one is made by the AHC to repair the abandoned building, while the second one will be the PLURAL renovation.

The Terrassa PLURAL renovation scheme is going to deploy a prefabricated ventilated façade in a part of the building, that will incorporate several technologies: The eAHC ventilation unit with integrated heating and cooling (by CVUT), high performance windows (by BGTECH) and photovoltaic panels.

FIGURE 1.6: WEST AND EAST FAÇADE TO BE RENOVATED OF THE TERRASSA BUILDING

1.2.3.2 Heating system type selection overview

In the Terrassa demonstration building, during the first phase of the renovation -before implementing PLURAL solutions-, a conventional heating system - based on individual electric heaters (radiators) - was installed in all the apartments. The electric radiators were included in the original heating design of the building and some of them were installed prior to the first phase refurbishment but never used.

In the second phase of the renovation with the PLURAL PnU kit two apartments from first floor will have, additionally, ventilation modules (of Reccuair and CVUT) close to the windows of each room - integrated in the prefabricated ventilated façade wall. These ventilation modules have an active heat recovery

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system and can also provide some heating and cooling utilizing the thermoelectric effect. However, according to their specifications, their heating capacity is limited as their main purpose is ventilation. The existing heating system (electric heaters) will be used for covering the rest of the heating demands of the interior spaces. (See D2.3 for more details).

Based on the number of rooms of the two apartments, three ventilation units will be installed per apartment, one per major space. If this system is seen as heating or cooling system, it includes both the source and the terminal unit for providing heating and cooling.

Considering all the above, no other centralized heating system will be used at the Terrassa demonstration building. The basic heating system of the apartments is considered the existing one (electrical radiators) and it will be supplemented by the recovery ventilation units with the thermoelectric module.

1.2.4 Virtual demonstration buildings and selection of heating and cooling systems

Apart from the three real demonstration buildings that are described in the previous sections, PLURAL will simulate its solutions to another three buildings. These three virtual renovations will test the same solutions adjusted to the characteristics of the buildings, their locations, as well as the national regulations. In addition, the virtual renovation will keep similar characteristics with real renovations the have been already implemented at these buildings. This will be done for a comparison between the virtual renovation of PLURAL and the real renovation to be possible. The three virtual demonstration buildings are in Bern – Switzerland, Berlin – Germany and Väsby – Sweden.

As it was concluded in the previous sections, heating (and cooling) system selection for the demonstration buildings strongly depends on the PLURAL technologies that are applied. In the following table the PNUs that are going to be simulated at the virtual demonstration buildings are presented, as it is described in D7.1 – "Preliminary design".

TABLE 1.2: PLURAL TECHNOLOGIES SELECTION FOR VIRTUAL DEMONSTRATION BUILDINGS

Virtual demonstration building	Building type	PLURAL technologies
Bern – Switzerland	Multifamily building (4-storey)	eWHC, prefab timber façade, innovative windows and BIPV

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Berlin – Germany	Single Family House	SmartWall with timber frame (fan coils, toolbox and innovative windows integration)
Väsby – Sweden	Multifamily building (8-storey)	eWHC, prefab timber façade, high performance windows

Based on Table 1.2, Bern and Väsby building will be virtually renovated with external heating and cooling system with the integrated water piping (eWHC), the same as the real Czech demonstration. The heating system should be a similar to the real case and it will be an air to water heat pump in order to simulate the delivery of hot water to the eWHC. The same stands for the Berlin virtual case as the terminal systems will be fan coils as in the real demonstration building in Voula. An air to water heat pump is also the ideal system for this virtual case. What will be different from the real demonstration buildings will be the capacities and the number of the modelled heat pumps where necessary.

In any case, the final selection of the specific type model and number of heat pumpσ for every virtual renovation case will be determined in Task 7.5 – "PLURAL systems installation at virtual demo buildings – Energy performance modelling for all demo cases", where the buildings will be fully modelled and simulated. All selected heat pumps will be by DAIKIN and all necessary data are going to be provided. Apart from air to water heat pump a ground source heat pump type maybe also selected for some of the Virtual demos due to the higher efficiencies for heating especially for the harsh winters of the demonstration case locations.

2 Heating & Cooling profiles and loads of the demonstration buildings

In this chapter the various profiles of the building's operation will be presented. Heating and cooling loads (where applicable) are also calculated for the sizing of the respective systems.

2.1 Greek demonstration building

In order to proceed to the dimensioning of the heat pump system along with the fan coils sizing needed for each living space of the two apartments under renovation, the calculation of the heating and cooling loads was conducted for the existing and the renovated state of the apartments. Different scenarios for the U-values of the renovated walls were considered so as to include all the possible cases (better or worse), as the final U-values of the SmartWall panels, will be calculated in situ during *Task 4.5 "PnU kit testing campaign"*. The final results were based on an average U-value which was considered to be as close to the reality as possible. Besides, minor changes in the final U-value of the walls, will not affect the dimensioning of the heating and cooling system.

For concluding about the systems that will be finally installed in combination with the SmartWall panels, different simulation software was also utilized in order to define different parameters and investigate different scenarios. The software used was 4M Adapt software, Energyplus and TEEKENAK software. All three of them are complying with the European standards and regulations and are also complying and in extend required by the Greek Authorities and Regulations. The calculations have followed the KENAK Regulation and the Greek Technical Directives accompanying the Regulation.

As each of the aforementioned software is based on different standards and calculation methods, in this report, it was decided to present the results that were used for selecting the capacity and number of fan coils and heat pumps, produced by 4M simulation program, which is the accepted by the Greek authorities, software.

In order to reduce as much as possible, the heating and cooling loads of a building, it is essential to select and design electromechanical technical systems which with their efficient operation will eliminate the energy losses. The design and study of the electromechanical systems that will be installed either in a new or an "under renovation" building, should involve:

- The type/use of the building: house, office, supermarket etc.
- The occupancy profiles and operation hours of the building.
- The separation of the building into spaces with different characteristics and different heating and cooling demands, or different operating conditions (thermal zones).
- The location of the building along with its area's climatic characteristics.
- The possibility of using natural lighting and ventilation.

- The available in the market automation and/or control solutions for the energy management of the HVAC systems.

In any case the installation and use of the proposed electromechanical systems entails the abidance with the general requirements set by the related to the CE mark, provisions.

The parameters that are usually considered in the energy and load calculations concern mainly the technical characteristics and the operating conditions of the HVAC and DHW systems under question. Their efficiencies depend on their proper dimensioning, their structure quality, their regular maintenance and their rational use.

The heating and cooling systems are designed and dimensioned in such a way, so as to be able to cover the heating and cooling demands in the most unfavourable environmental conditions, as these are specified in the related directives and regulations (Greek Technical Directive for the “Climatic data of the Greek regions”). During the heating or cooling period, the external environmental conditions are constantly changing, both on a daily and hourly basis. As a result, each HVAC system is mainly operating under partial load conditions, which reduces its actual efficiency when compared with its nominal one. Hence, the design of the heating and cooling systems should be based on the real conditions and be able to cover the partial loads in the most efficient way.

The energy analysis of the Voula demo case was carried out by means of EnergyPlus software (by NTUA) and TEE-KENAK software (by AMS). The whole building was drawn in SketchUp. However, only the first floor was drawn in detail, separating each room as a unique thermal zone. For this reason, Apartment A1 was separated into 8 thermal zones, while Apartment A2 was separated into 7 thermal zones. Figure 2.1 illustrates the whole building, drawn in SketchUp, while Figure 2.2 presents the thermal zones of the demo case (first floor).

The demo case (first floor) is shaded by three different ways:

- neighbour buildings
- balcony canopies at the three orientations
- shading devices (on summer months)
- window shading devices (roller shutters).

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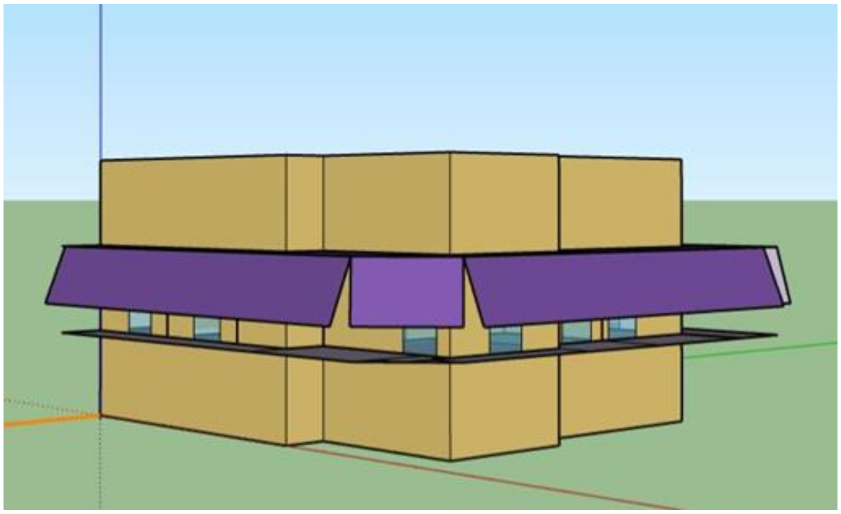

FIGURE 2.1: THE VVV DEMO CASE IN SKETCHUP

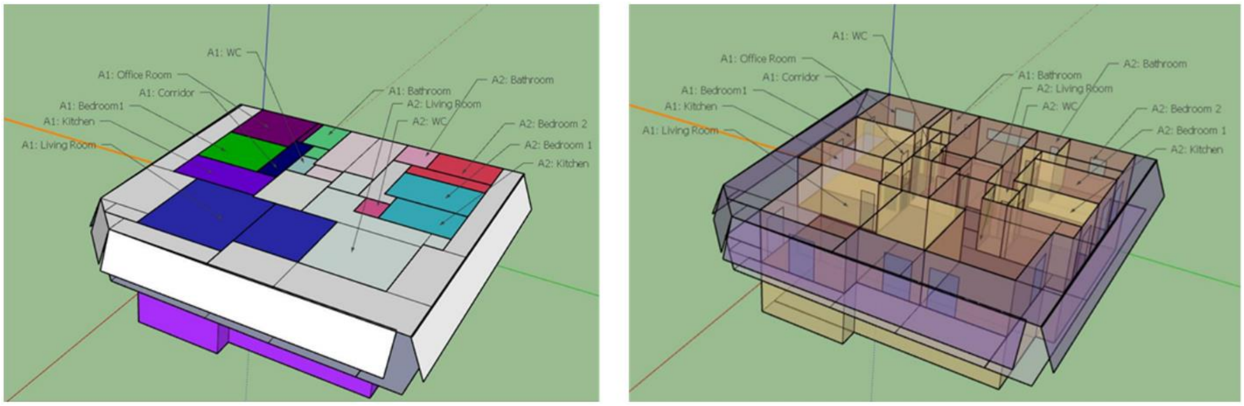

FIGURE 2.2: SEPARATION OF THERMAL ZONES

The same reasoning – assumption for the thermal zones was followed also when simulating on the 4M software, so as to calculate the thermal losses and cooling loads for each room of the apartments.

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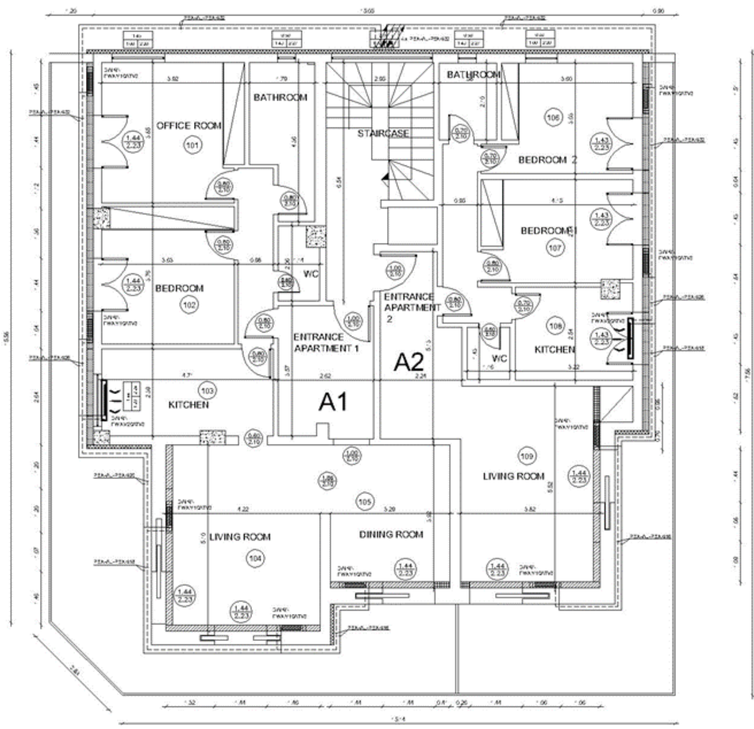

FIGURE 2.3: FLOOR PLAN OF THE TWO APARTMENTS & NAMES OF EACH SPACE – ROOM

In the following tables (Table 2.1 & Table 2.2) the peak values for the heating and cooling loads are presented as calculated by the 4M software based on the DIN77 and CARRIER standards correspondingly, as well as the DHW consumptions before and after the renovation as calculated by the TEEKENAK software.

TABLE 2.1: HEATING – COOLING DEMANDS FOR A1 APARTMENT AND DHW DEMANDS/CONSUMPTION

Zones	Heating Peak Values [W]		Cooling Peak Values [W]		DHW
	Existing State	**Renovated State**	**Existing State**	**Renovated State**	**Demands on DHW [kWh/m²]**
Living – Dining Room	4225	1603	3230	2305,6	15,1
Kitchen	1305	549	3105	2376,3	

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Bedroom1	1181	414	891	800,7		
Office Room	2186	694	1108	763,5		
Toilet	785	692	397	388		
WC	164	164	170	170		
Hall	332	332	441	456		
Corridor	45	45	192	192		
Total	10.223	4.493	9.534	7.452	**Energy Consumption Existing [kWhr/m²yr]**	**Energy Consumption Renovated [kWhr/m²yr]**
					15,4	5,3

TABLE 2.2: HEATING – COOLING DEMANDS FOR A2 APARTMENT AND DHW DEMANDS/CONSUMPTION

	Heating Peak Values [W]		Cooling Peak Values [W]		DHW	
Zones	**Existing State**	**Renovated State**	**Existing State**	**Renovated State**	**Demands on DHW [kWh/m²]**	
Living Hall	3091	1383	2393	1805.9		
Bedroom2	1771	551	1122	796.1		
Bedroom1	950	357	659	592.3		
Kitchen	1090	474	2955	2238.6	20,0	
Toilet	593	430	333	239		
WC	18	16	141	141		
Cor	248	248	223	223		
Total	7.761	3.459	7.826	6.035,9	**Energy Consumption Existing [kWhr/m²yr]**	**Energy Consumption Renovated [kWhr/m²yr]**

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					20,4	7,0

2.1.1 *User & occupancy profiles*

The building operation is characterized by a number of schedules that are selected to represent the behavior of certain parameters significant for the overall energy performance and indoor environment. As a guideline, the schedules used to depict the existing state of Voula demo site, are a mixture of European (EN)/Greek building regulation and ASHRAE. EN/Greek standards are followed to determine the heating/cooling season whereas, ASHRAE hourly profiles are used for occupancy, HVAC, hot water and electricity load schedules. This combination is useful in order to provide more "realistic" typical occupancy and behavior profiles for residential mid - rise apartment buildings.

For the calculation of the heating and cooling loads and depending on the climatic zone of the building's location, specific heating and cooling periods are considered. Moreover, it is worth noting that the operation hours and the applied heating and cooling schedules, are greatly affecting the efficiency of the systems, as well as the thermal comfort of the occupants. Usually, a continuous heating/cooling schedule results in better systems' performances and less energy consumptions, in relation with any intermittent schedule. However, in the case of Voula demo site, where 18 hours/day of heating are assumed (due to the residential use of the building –Table 2.3), the resulting efficiency and performance of the building is quite satisfying as these 18 hours of continuous operation create a more or less stable environment inside the spaces.

In Table 2.3, the operating/occupancy schedule per use or type of building is presented, as derived from the Greek Technical Directives accompanying the KENAK regulation (for keeping this report as brief as possible not all the building uses are presented here, but only the most representative ones).

TABLE 2.3: TYPICAL OPERATION HOURS PER BUILDING USE

Basic Building Categories	Building Use	Hours of Operation	Days of Operation/Week	Operation Period in months
Residence	**Single family house, apartment building**	**18**	**7**	**12**
Temporary accommodation	Hostel/Pension (yearly operation)	24	7	12
	Hotel's bedroom	24	7	12
	Hotels etc.	24	7	12

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Public places	Restaurant	12	7	12
	Theatres, Cinemas	7	7	12
	Museums	6	7	12
	Banks	8	5	12
	Coffee shops	15	7	12
Education	Kindergarten	8	5	9
	Primary, Secondary Education	8	5	9
Offices	Offices	10	5	12

In addition, for the heating and cooling loads calculations, specific heating and cooling periods are considered for each building, depending on the climatic zone of the building:

- For climatic zone A and B

Heating period: 1st November to 15th April

Cooling period: 15th May to 15th September

- For climatic zone C and D

Heating period: 15th October to 30th April

Cooling period: 1st June to 31st August

Taking into account the data that correspond to the occupancy and operation schedule of the residential buildings, the following table has been produced showing the hourly operation schedule for heating, cooling, and DHW for Voula demo building (ventilation is presented under *D2.3 "Ventilation systems selected for each demo site"*).

Table 2.4: Daily operation Profiles for Heating, Cooling and DHW

Occupancy	Seasonal	365 days

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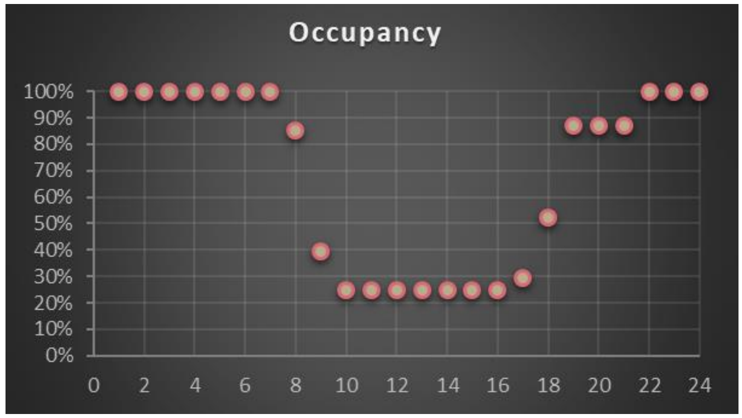
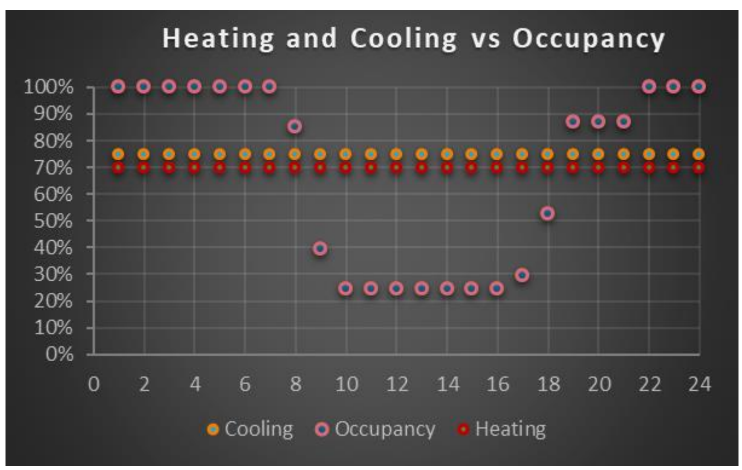
<table>
<tr><td rowspan="2"></td><td>Approximate daily operating hours</td><td>18 hours [1]</td></tr>
<tr><td>Hourly</td><td>
</td></tr>
<tr><td rowspan="3">Heating - Cooling</td><td>Heating season</td><td>1st November - 15th April [2]</td></tr>
<tr><td>Cooling Season</td><td>15th May – 15th September</td></tr>
<tr><td>Hourly</td><td>
</td></tr>
<tr><td>Hot water</td><td>Seasonal</td><td>365 days</td></tr>
</table>

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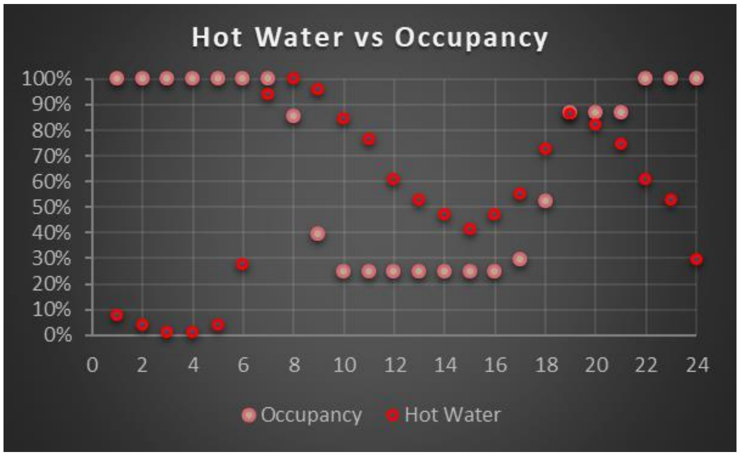
	Hourly	

[1] According to Greek Building regulations (KENAK - TOTEE 20701-1)

[2] Period according to Greek regulations (KENAK - TOTEE 20701-1), for climatic zones A and B

2.1.2 Heating loads calculation

Description of the assumptions and parameters

Thermal losses, cooling loads calculation and dimensioning of the fan coils, was conducted by 4M software. Energy analysis was outlined by Energy Plus, whereas the energy consumptions and primary energy consumptions, along with the energy classification of the renovated area were specified by the TEEKENAK software.

More specifically, for the thermal losses calculation which will define the heating demands of the renovated state of the building, the following parameters were considered in the 4M software:

- Climatic Data according to KENAK regulations for Athens
- Required internal temperature at 20°C
- Temperature of the non-conditioned spaces at 10°C
- Ground temperature at 10°C
- Average annual external temperature (for Athens) at 18.6°C
- Calculation method per DIN 4701/ 77 standards
- Heating Schedule, from 06.00 to 24.00 (18 hours of operation and 6 hours of interruption)
- U-value of walls after the SmartWall installation at 0.4W/m^{2}K
- U-value of walls where ETICS will be installed at 0.5 W/m^{2}K
- U-value of windows at 1.3 W/m^{2}K. It is assumed that the windows of the bathrooms and WCs will not be replaced as they were replaced during the 1st stage Renovation Works of Voula demonstration building.

The assumptions for the heating loads calculations according to DIN 4701/77 are described in detail in Annex 6.1.

Building related assumptions and input parameters:

In the following tables all input parameters for calculating the heat losses of the building are presented. Among them are the thermal properties of its structural elements.

City	Athens – Helliniko Region (KENAK)
Average min outdoor temperature (°C)	3.0
Desired indoor temperature (°C)	20
Temperature of non-conditioned spaces (°C)	10

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Ground temperature (ºC)	10
Calculation method	DIN77
Unit systems	Watt

TABLE 2.5: TYPICAL BUILDING ELEMENTS – EXTERIOR WALLS

Ex. Walls	Description	k or U-value of exterior walls (Watt/m2K)
W1	Existing walls with SmartWall	0.4
W2	Existing walls with ETICS	0.5

TABLE 2.6: TYPICAL BUILDING ELEMENTS – INTERIOR WALLS

In. Walls	Description	k or U-value of interior walls (Watt/m^{2}K)
E1	Interior masonry	1.8

TABLE 2.7:TYPICAL BUILDING ELEMENTS – FLOORS

Floors	Description	K or U-value of (Watt/m^{2}K) floors
F1	Marble floor in contact with a non-heated space, uninsulated	2

TABLE 2.8: TYPICAL BUILDING ELEMENTS – OPENINGS

Openings	Description	Width (m)	Height (m)	K or U-value (Watt/m^{2}K) openings	Coef. a	Layers
O1	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	1.2	2
O2	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	1.2	2

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O3	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	1.2	2
O4	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	1.2	2
O5	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	1.2	2
O6	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	1.2	2
O7	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	1.2	2
O8	Double with gap 12mm (PVC frame)	0.88	1.20	1.3	1.2	1
O9	Double with gap 12mm (PVC frame)	0.6	0.84	1.3	1.2	1
O10	Double with gap 12mm (PVC frame)	2.76	0.65	1.3	1.2	2
O11	Double with gap 12mm (PVC frame)	0.50	0.84	1.3	1.2	1
O12	Double with gap 12mm (PVC frame)	1.45	1.20	1.3	1.2	2
O13	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	1.2	2
O14	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	1.2	2
O15	Double with gap 12mm (PVC frame)	1.44	0.95	1.3	1.2	2
O16	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	1.2	2
O17	Opening without glass/Wooden Door	1	2.1	3.48	1.2	1

In the following tables the heat losses for each room of the two apartments and the total heat losses per apartment under renovation are presented:

TABLE 2.9: HEAT LOSSES PER ROOM & PER APARTMENT

No.	Room Name	Q_{tot} (W)	Property
1	HALL – A1	332	A1
2	LIVING & DINING ROOM – A1	1603	A1
3	KITCHEN – A1	549	A1
4	BEDROOM 1 – A1	414	A1
5	OFFICE ROOM – A1	694	A1
6	BATH – A1	692	A1
7	CORRIDOR – A1	45	A1

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8	WC – A1	164	A1
9	HALL / LIVING ROOM – A2	1383	A2
10	KITCHEN – A2	474	A2
11	BATH – A2	430	A2
12	CORRIDOR – A2	248	A2
13	WC – A2	16	A2
14	BEDROOM 1 – A2	357	A2
15	BEDROOM 2 – A2	551	A2
TOTAL LOSSES		**7950**	

TABLE 2.10: TOTAL HEAT LOSSES PER APARTMENT

No	Property	Q (W)
1	A1	4492
2	A2	3458

Heat losses per single room of the two apartments are calculated and presented in tables that can be found in Annex 6.2.

2.1.3 Cooling loads calculation

The current study was conducted based on the Carrier methodology, following also the guidelines of 2425/86 TOTEE and exploiting the following handbooks:

a. Recknagel-Sprenger, Taschenbuch fuer Heizung und Klimatechnik
b. VDI Kuehlastregeln, VDI 2078
c. Carrier Handbook of Air Conditioning System Design

Following Carrier methodology, space cooling load (or heat gain) results from the sum of loads corresponding to the reasons and assumptions that are presented in detail in Annex 6.1.

Building related assumptions:

Climatic data for	Athens – Helliniko region (KENAK)
Required internal humidity	50%
Required indoor temperature	26 (°C)
Difference between external temperature and non-conditioned spaces temperature	5 (°C)
Difference between ground temperature and indoor temperature	-5 (°C)
Number of building floors	1
Typical floor height	3.3 (m)
Calculation methodology	CARRIER
Unit systems	Watt

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TABLE 2.11: TYPICAL BUILDING ELEMENTS – EXTERIOR WALLS

Ex. Walls	Description	Type ASHRAE CLTD	Type ASHRAE TFM	Type ASHRAE RTS	k or U-Value W/m²K	Weight kg/m2
W1	Existing wall with SmartWall	C	G11	17	0.4	300
W2	Existing wall with ETICS	C	G11	17	0.5	300

TABLE 2.12: TYPICAL BUILDING ELEMENTS – INTERIOR WALLS

In. Walls	Description	k or U-Value W/m²K
I1	Interior masonry	1.8

TABLE 2.13: TYPICAL BUILDING ELEMENTS – FLOORS

Floors	Description	k or U-Value W/m²K
F1	Marble floor in contact with non-conditioned space, uninsulated	2

TABLE 2.14: TYPICAL BUILDING ELEMENTS – OPENINGS

Opening	Description	Width.(m)	Height (m)	k or U-value W/m²K	Window Coef.	Frame type	Coef. a	Glass system
O1	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	0.9	1		19

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O2	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	0.62	1		1
O3	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	0.62	1		1
O4	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	0.62	1		1
O5	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	0.62	1		1
O6	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	0.62	1		1
O7	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	0.62	1		1
O8	Double with gap 12mm (PVC frame)	0.88	1.20	1.3	0.62	1		1
O9	Double with gap 12mm (PVC frame)	0.6	0.84	1.3	0.62	1		1
O10	Double with gap 12mm (PVC frame)	2.76	0.65	1.3	0.62	1		1
O11	Double with gap 12mm (PVC frame)	0.50	0.84	1.3	0.62	1		1
O12	Double with gap 12mm (PVC frame)	1.45	1.20	1.3	0.62	1		1
O13	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	0.62	1		1

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O14	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	0.62	1		1
O15	Double with gap 12mm (PVC frame)	1.44	0.95	1.3	0.62	1		1
O16	Double with gap 12mm (PVC frame)	1.44	2.23	1.3	0.62	1		1
O17	Opening without glass (wooden frame)	1	2.1	3.48	1	1		

The analytical calculations for the cooling loads of each room are presented in corresponding tables in the Annex 6.2, whereas in the following table the total cooling load per room is depicted.

TABLE 2.15: COOLING LOADS FOR EACH ROOM OF THE TWO APARTMENTS*

Space	System	Surface area (m^2)	Max load time	Exterior air (m^3/h)	Total load (with vent/tion) (W)	Total sensible load (with vent/tion) (W)	Total latent load (with vent/tion) (W)	Sensible load per m^2 (W/m^2)	Total load per m^2 (W/m^2)
LIVING ROOM–A1	1	37.6	17	62.0	2305.6	1817.3	488.3	48.3	61.3
KITCHEN –A1	1	11.3	15	55.8	2376.3	1758.3	618.0	155.9	210.7
BEDROOM 1–A1	1	13.3	15	22.0	800.7	607.6	193.1	45.6	60.1
OFFICE ROOM–A1	1	14.8	15	24.5	763.5	559.3	204.2	37.7	51.5
HALL / LIVING ROOM–A2	2	32.0	17	52.8	1805.9	1359.0	446.9	42.5	56.4

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KITCHEN –A2	2	8.0	15	39.6	2238.6	1693.4	545.2	211.7	279.8
BEDROOM 1–A2	2	11.5	15	18.9	592.3	412.8	179.5	36.0	51.6
BEDROOM 2–A2	2	10.5	15	17.3	796.1	623.8	172.2	59.4	75.8
Total		**139**		**293**	**11679**	**8831.6**	**2847.3**	**63.5**	**84.0**

**The cooling loads of the halls, corridors and bathrooms are not included in the above table, as no cooling is usually applied in these living areas.*

2.1.4 DHW load and demand

The domestic hot water (DHW) demand and consumption have been calculated via the TEEKENAK software (already depicted in Tables 2 and 3 above), whereas the heating load and the solar energy received from the solar collectors were calculated by the 4M software, as well as the Valentin T*SOL software[2], which was used to compare different hot water production systems.

Moreover, the 4M software was utilized again to define the routing and characteristics of the new plumbing piping system that will be installed in order to connect the solar collectors with the existing hygiene receptors/appliances (sinks, bathtubs, etc.). The piping for the domestic hot water will follow the same path as the piping of the heating and cooling system, hence, it will start from the solar panels on the building's roof and will end in the small loft of each apartment, which is located on the top of the bathroom ceiling (where is currently installed the existing DHW electric boiler). For the DHW supply, the internal existing pipework of the building will be used as its condition is in a good state, but the existing electric boiler will be removed from the bathroom's loft.

All the aforementioned information along with the calculations conducted for the DHW demands and piping system will be presented under *Task 2.5 "Energy systems integration (harvesting & storage) – PLURAL toolbox"* and its related deliverable (D2.5).

[2] https://valentin-software.com/en/products/tsol/

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2.2 Czech demonstration building

2.2.1 User & occupancy profiles

The Czech norm CSN 730331 defines a specific internal gain due to occupancy (2.0 W/m^2) but does not define an hourly profile. For that reason, the hourly profile coming from the Swiss norm SIA 2024 was assumed for the occupancy profile. Due to the presence of inhabitants, a humidity source of 2.7 g/(h·m^2) was assumed in the model (i.e., 80 g/(h·P)). These internal gains were assumed for all the thermal zones, except for staircases, cellar rooms and storage rooms.

With regards to equipment and lighting, benchmark numbers of the latest study of Czech Statistical Office[3] show an electricity consumption (for lighting, appliances, cooking and other) of 28.6 kWh/m^{2}y for dwellings in SFH. In order to get the defined electricity consumption, a specific internal gain of 5.5 W/m^2 was assumed for lighting and appliances, using a plausible electric power profile processed statistically by Czech energy market operator (Figure 2.4)

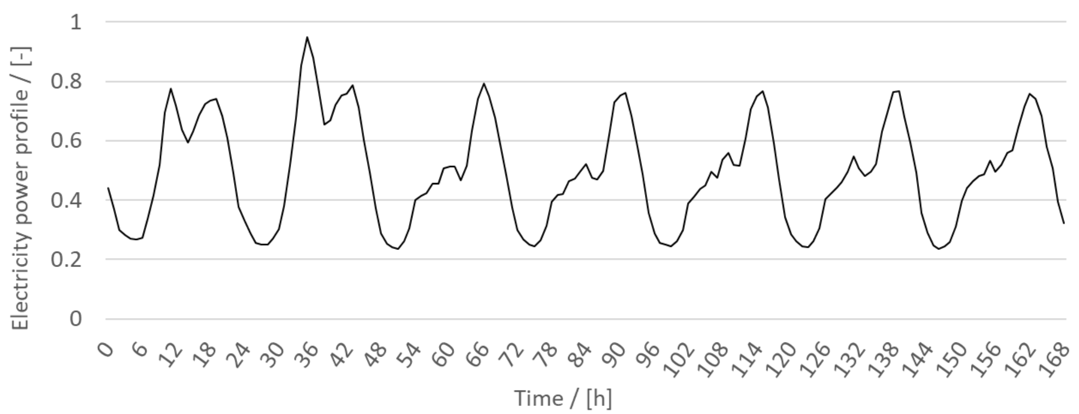

FIGURE 2.4: ELECTRICITY POWER PROFILE FOR A TYPICAL WEEK (SOURCE: CZECH ENERGY MARKET OPERATOR) – FIRST DAYS IS SATURDAY

2.2.2 Heating loads calculation

The heat load calculation for the real demo building of Kasava was carried out according to the national norms CSN 73 0331-1 and CSN 73 0540 – Part 3. The building was simulated with a set point room temperature of 20.0 °C and a constant ambient temperature of -15.0 °C. A constant infiltration rate of 0.2 per h was considered for all the thermal zones, while gains (i.e., solar gains and internal gains) were

[3] https://www.czso.cz/documents/10180/50619982/ENERGO_2015.pdf/86331734-a917-438a-b3c2-43a5414083fc?version=1.4

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set to zero. The building was simulated with an "ideal" heating system. Figure 2.5 shows the floor plans of the building, in which the name of each room and the decentralized ventilation units are highlighted.

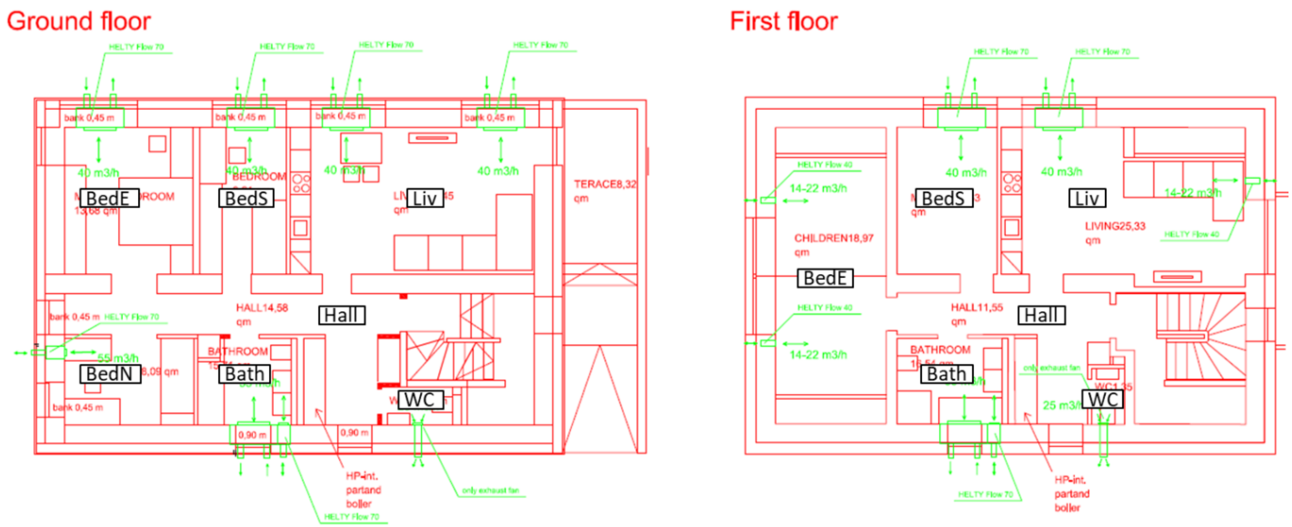

FIGURE 2.5: FLOOR PLANS OF THE BUILDING IN KASAVA – GROUND FLOOR (LEFT) AND FIRST FLOOR (RIGHT). VENTILATION UNITS (IN GREEN) FOR THE DIFFERENT ROOMS OF THE BUILDING ARE INDICATED.

Figure 2.6 shows the heat load for each room of the building and the specific heat load. As the heat is delivered through the external wall, the heat load related to the active heating wall is shown. The specific heat loads vary from 17 W/m^2_{NHA} to 70 W/m^2_{NHA} depending on the room. If the whole building is considered, a total maximum heat load of approximately 6 kW was calculated.

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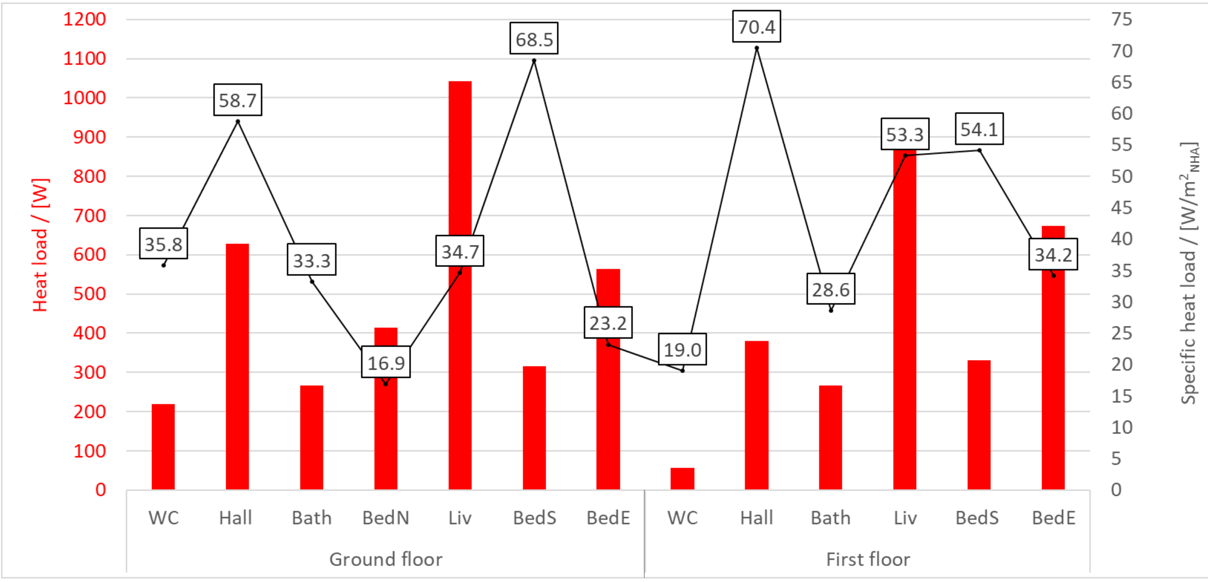

Figure 2.6: Heat load (left axis) and specific heat load (right axis) for each room of the building – "NHA" is the net external wall (ext. wall area minus window area) that is thermally activated with the eWHC

2.2.3 DHW profile

A reference DHW load profile (see Figure 2.7) for a single-family house was assumed (IEA SHC Task44 **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**) with an energy demand for DHW of 2133 kWh/a for each apartment (4266 kWh/a for the whole building).

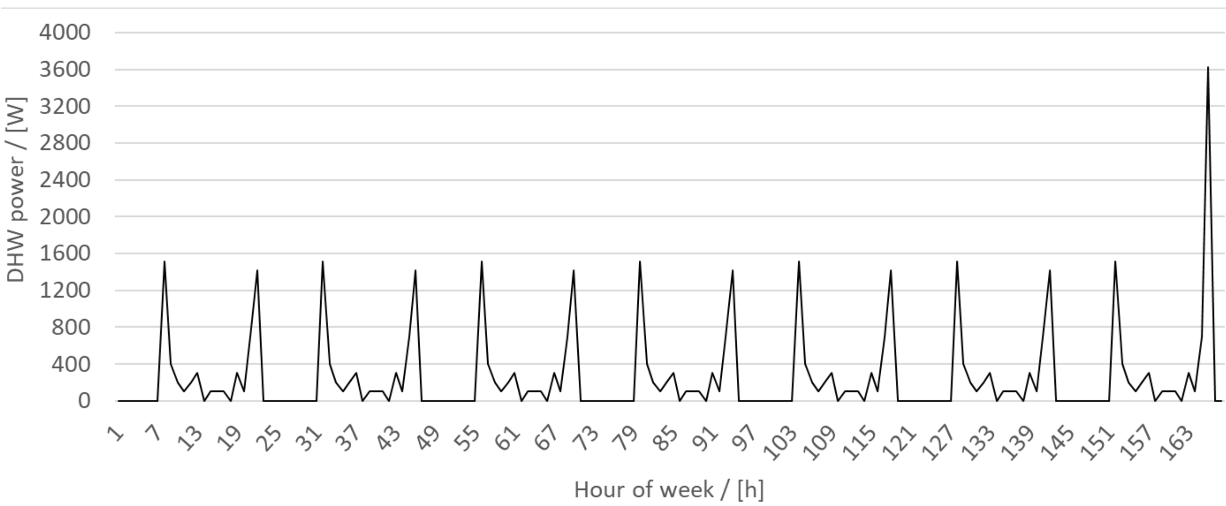

Figure 2.7: DHW power [W] for a typical week for each single apartment – 2133 kWh/a for each apartment, 4266 kWh/a for the whole building

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2.3 Spanish demonstration building

The following sections describe the boundary conditions assumed for the simulation of the demo case of Terrassa (i.e., Spanish demo case). Regulatory conditions from the Spanish national building code for user behaviours and internal gains profiles are defined. This information can be also found as is in Deliverable D3.3 as no further updates since then have been realized.

Only floors 1 and 2 of the Terrassa demo site will be affected by the PLURAL renovation.

PLURAL Terrassa window U-value: 1.0 W/m^{2}K

PLURAL Terrassa window g-value: 53%

PLURAL Terrassa external wall U-value: 0.201 W/m2K

Terrassa roof (pre-PLURAL values only, no PLURAL renovation to be applied on the roof for Terrassa) U-value: 0.37 W/m2K

Ground floor: 356.64 m^2

(PLURAL) 1st floor: 357.65 m^2

(PLURAL) 2nd floor: 357.65 m^2

3rd floor (duplex): 207.74 m^2

Total building: 1.280 m^2 (in PLURAL block)

FIGURE 2.8: WEST AND EAST EAÇADE TO BE RENOVATED OF THE TERRASSA BUILDING

The 2 underground levels, with the car park, is not considered in this total building area)

TABLE 2.16: AREA OF EVERY FAÇADE TO BE RENOVATED FOR EVERY ORIENTATION

Façade area per orientation [m^2]	North	Partition wall up to the second floor in contact with the adjoining local. This wall is exterior -30m^2- in the latest level (duplex).
	East	295.76 m^2
	South	Partition wall up to the first floor in contact with the adjoining residencial building. The wall is exterior – 68m^2- in the 2nd and 3rd floors.
	West	288.4 m^2

For the Terrassa demonstration site the PLURAL renovation includes the incorporation of the eAHC unit. This is a ventilation unit with an active element (Peltier cell) for conditioning the supply air before it enters the zone. Its primary purpose is to improve the Indoor Air Quality (IAQ) and not provide heating

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or cooling. Via TRNSYS simulations we calculated that the eAHC unit implies an average increase of heating and cooling consumption of +4.45% and +1.62% respectively.

2.3.1 User & occupancy profiles

Thermal comfort

Regulatory profiles

The Spanish regulation proposes operation set-points for the cooling season (June – September): 27°C during night and 25°C during afternoon. During the morning - noon hours the building is on a free-floating profile. For the heating season (October – May), the temperature set-points are: 17°C during the night and 20°C during the whole day. The profiles for heating and cooling are shown in Figure 2.9 and Figure 2.10 respectively.

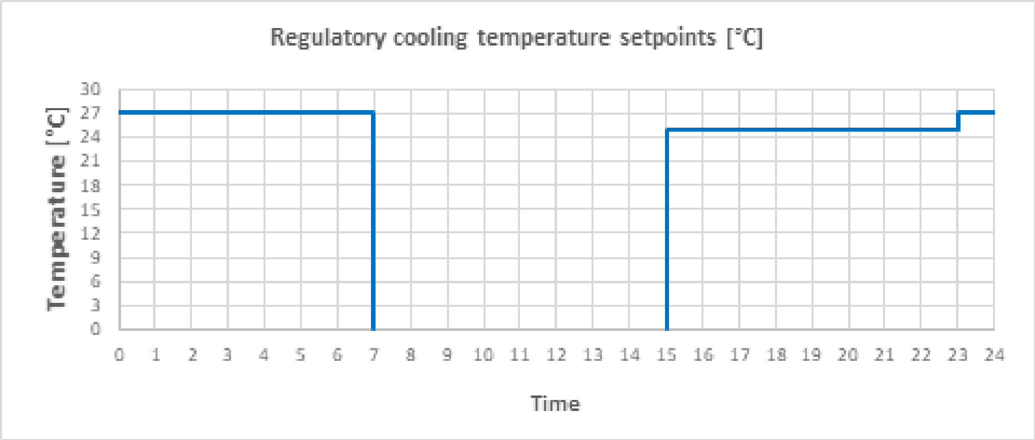

FIGURE 2.9: COOLING SEASON TEMPERATURE SETPOINTS - CTE

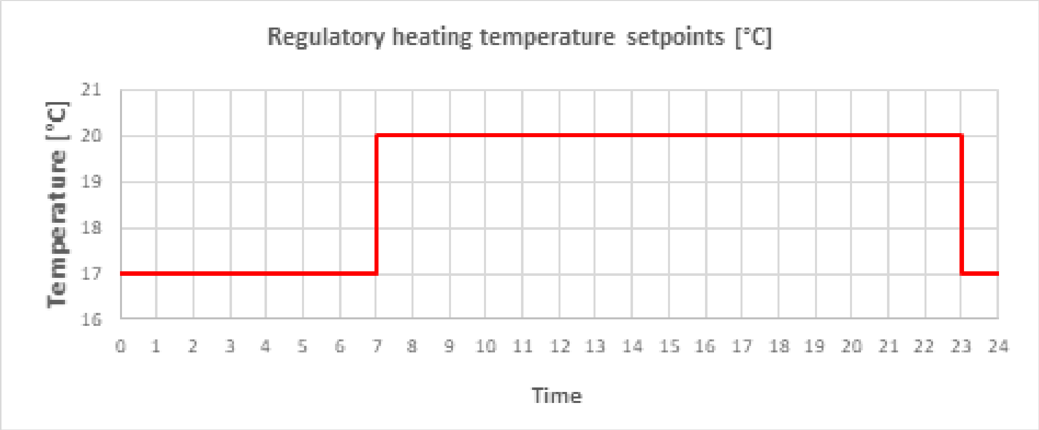

FIGURE 2.10: HEATING SEASON TEMPERATURE SETPOINTS - CTE

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TABLE 2.17: OCCUPANCY AND OPERATION PROFILES OF TERASSA BUILDING

Regulatory Heating & Cooling period – Occupancy profile	
Heating period	Oct. – May
Cooling period	Jun. – Sep.
Heating Set point	20 °C and 17 °C
Cooling Set point	27 °C, 25 °C and free floating
Daily heating schedule	17 °C [23:00 – 07:00], 20 °C [07:00 – 23:00], free floating rest of the time
Daily cooling schedule	27 °C [23:00 – 07:00], 25 °C [15:00 – 23:00], free floating rest of the time

Ventilation and infiltration

Regulatory profiles

The current building prior to renovation has no mechanical ventilation or any air handling unit (AHU) equipment. Only in the wet zones of each dwelling, namely the bathroom and the kitchen, extraction fans are installed. According to the Spanish Building Code CTE the minimum air change rates are defined below:

- 1 room dwellings → 50.4 m^3/h
- 2 rooms dwellings → 86.4 m^3/h
- 3 rooms dwellings → 118.8 m^3/h

During summer, night ventilation between 00:00 - 08:00, by natural means, is assumed at a rate of 4 ac/h as indicated in CTE and only for the double frontage dwellings.

The infiltration equivalent leakage area (ELA) has been calculated according to the Spanish regulation for residential buildings. Pre-PLURAL renovation the ELA was calculated equal to 500 cm^2. Post PLURAL and only for the zones affected by the renovation (first and second floors) the ELA was calculated equal to 250 cm^2. For the rest of the building zones (ground and top floor), the ELA remained 500 cm^2.

Internal gains

Regulatory profiles

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The national Spanish Building Code CTE , defines the specific internal gains due to occupants, domestic equipment and lighting. Two different profiles for internal heat gains are defined, one for the weekdays and one for the weekends, shown in Figure 2.11 and Figure 2.12 respectively.

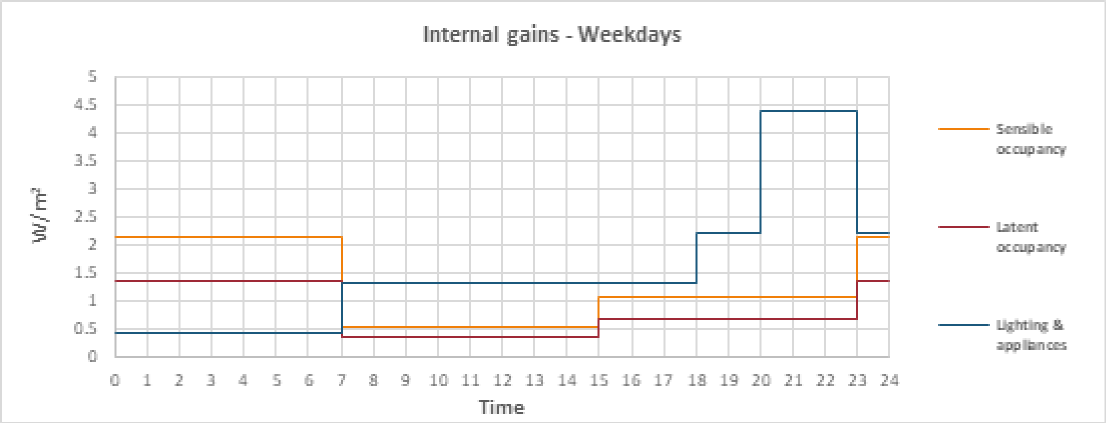

FIGURE 2.11: HOURLY INTERNAL GAINS DURING THE WEEKDAYS

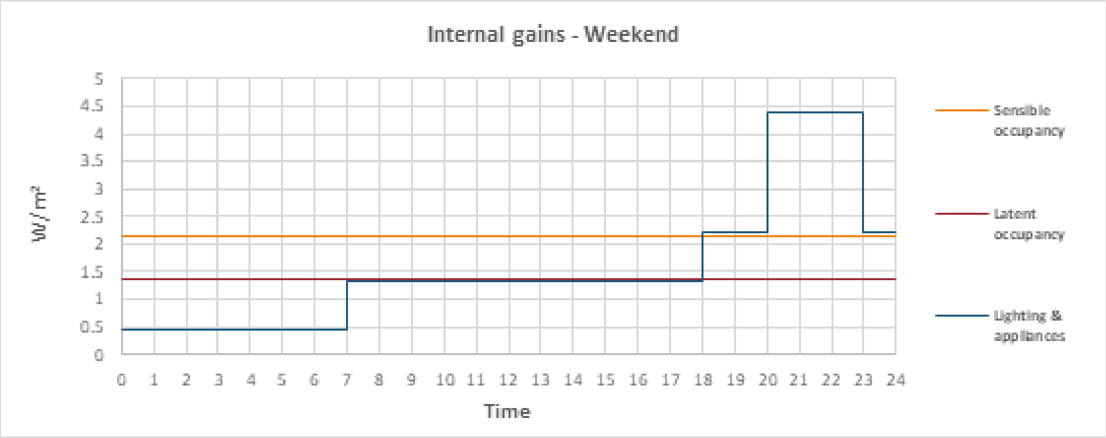

FIGURE 2.12: Hourly internal gains during the weekends

In which occupancy is represented by the sensible and latent heat gains due to persons, as introduced in the Spanish national regulation CT.

Window shading

Realistic profiles

The national Spanish Building Code CTE, does not specify hourly profiles for windows shading. Thus, only theoretical – realistic profiles were implemented. Before the PLURAL renovation, all the windows, shading devices and their schedules are the same for all the dwellings. Figure 2.13 shows the external

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shading profile applied to all the windows of all building zones before PLURAL renovation; 1 – external shading 100 % and 0 – no external shading. An optional additional external shading device was implemented in the simulations. The optional profile is found in Figure 2.14.

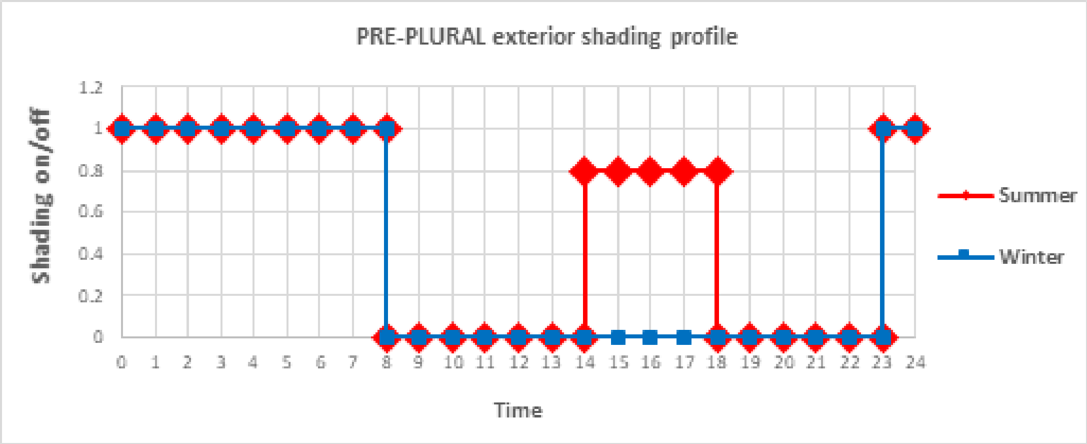

FIGURE 2.13: Pre-PLURAL external shading profile

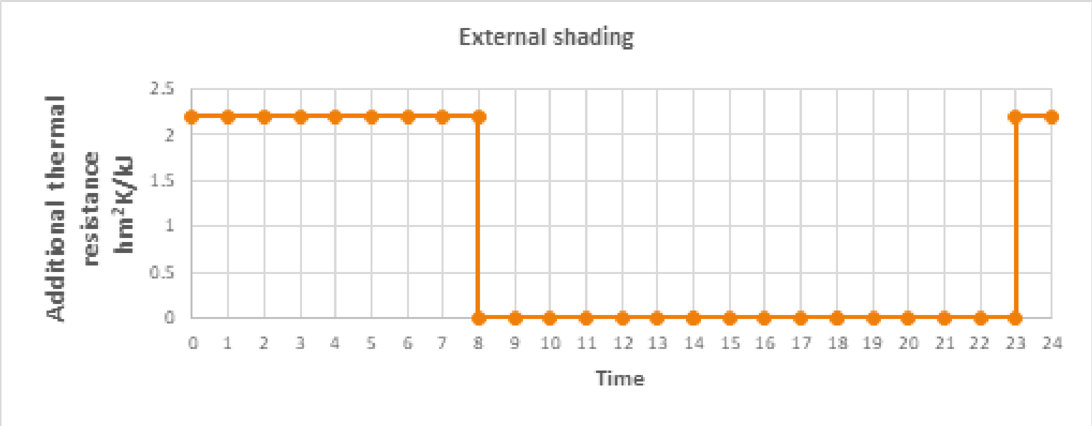

FIGURE 2.14: Additional thermal resistance due to external shading device

After the PLURAL renovation, the same profile as shown in Figure 2.13 was implemented for the windows of the floors 0 (ground floor) and 3 (top floor), as for these floors no PLURAL renovation took place. The PLURAL renovation only applied for floors 1 (first) and 2 (second). Figure 2.15 shows the external shading profile applied to all the windows of the first and second floor of the building, which are the only ones affected by the PLURAL renovation; 1 – shading 100 % and 0 – no shading. It can be observed that after the PLURAL renovation the external shading devices of the aforementioned floors never fully shut down and they are always at least 20 % open at all times.

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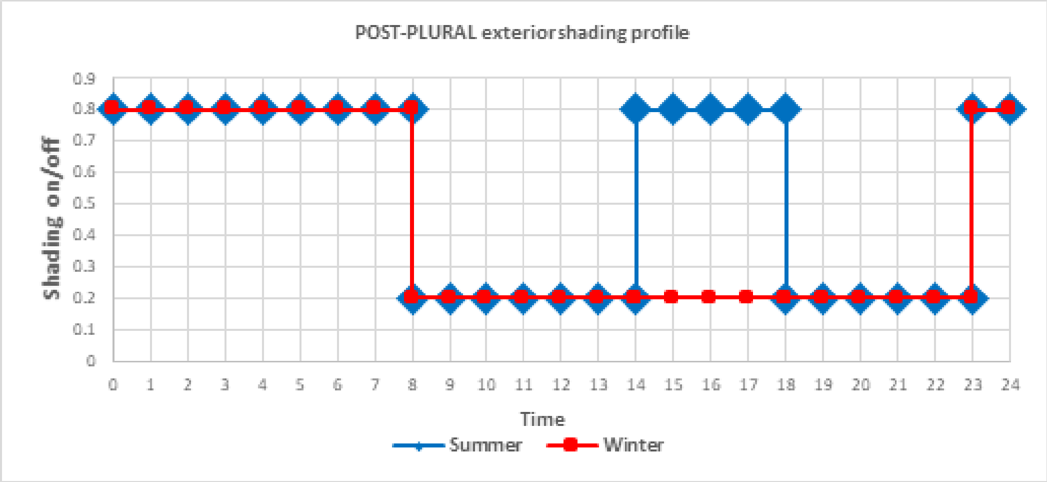

FIGURE 2.15: POST-PLURAL EXTERNAL SHADING PROFILE

2.3.2 Heating loads calculation

Table 2.18,Table 2.19 & Table 2.20 provide the peak losses for three representative dwellings and each of their zones for the Terrassa demo site that PLURAL will be applied. The values indicated are taken from simulation results and not via a sizing procedure.

TABLE 2.18: DOUBLE FRONTAGE ZONE PEAK LOSSES

Apartment 1 – double frontage (3 occupant apartment, 59.5 m^2)	PLURAL renovation heating load (heat losses) - kW	
Modelled as a single thermal zone	Transmission losses	Infiltration – Ventilation losses
Total	0.34	0.67

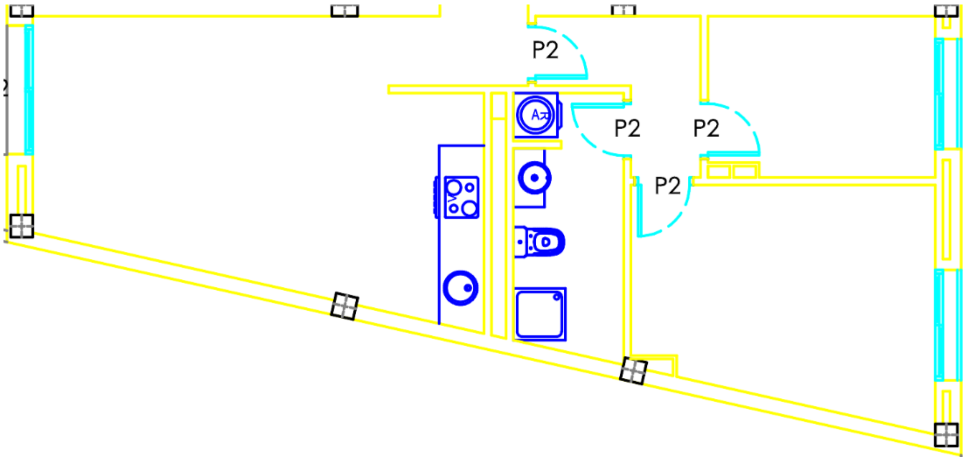

FIGURE 2.16: FLOOR PLAN OF THE APARTMENT 1 MENTIONED IN **TABLE 2.18** AND IS MODELLED AS A SINGLE THERMAL ZONE

TABLE 2.19: TWO-BEDROOM APARTMENT ZONES PEAK LOSSES

Apartment 2 – single frontage (3 occupant apartment, 50.1 m^2)	PLURAL renovation heating load (heat losses) - kW	
	Transmission losses	Infiltration – Ventilation losses
Living room and Kitchen - 25.6 m^2	0.27	0.81
Bedroom 1 (Master bedroom) - 12.5 m^2	0.13	0.1
Bedroom 2 (Small bedroom) - 6.9 m^2	0.07	0.07
Bathroom – 5 m^2	0.05	0.16
Total	0.52	1.14

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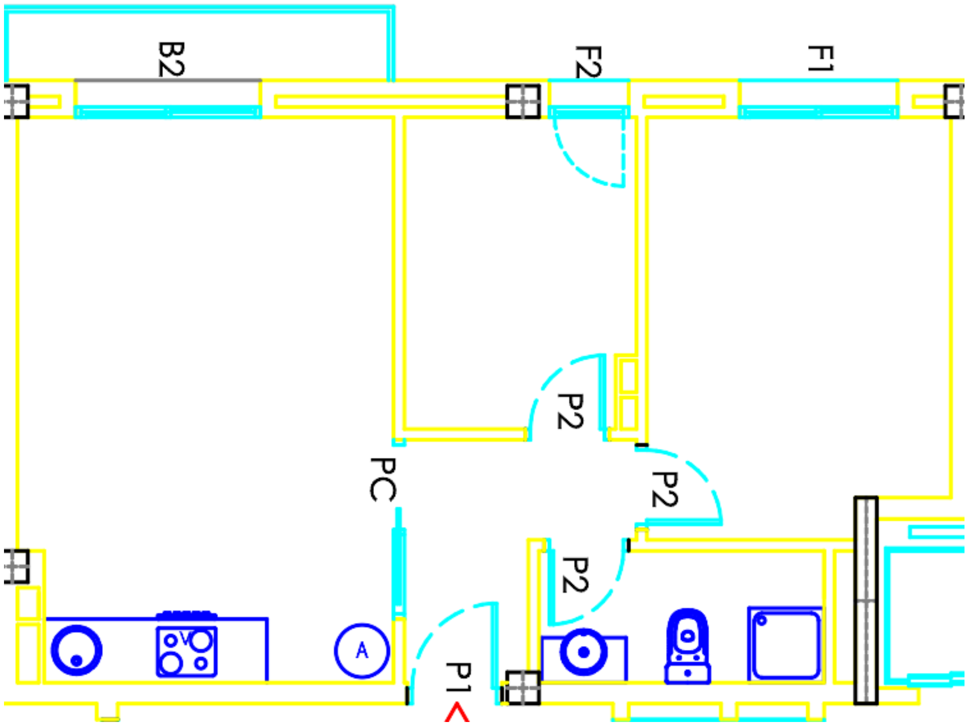

FIGURE 2.17: FLOOR PLAN OF THE APARTMENT 2 MENTIONED IN **TABLE 2.19**. TYPICAL TWO-BEDROOM APARTMENT OF THE TERRASSA DEMO SITE

TABLE 2.20: DUPLEX DWELLING ZONES PEAK LOSSES

Apartment 3 – two floor (4 occupant apartment, 79.5 m^2)	PLURAL renovation heating load (heat losses) - kW	
	Transmission losses	Infiltration – Ventilation losses
Living room and Kitchen (2nd floor) - 26.2 m^2	0.3	0.6
Common area (3rd floor)* - 28.3 m^2	0.84	0.75
Bedroom 1 (Master bedroom, 2nd floor) - 10 m^2	0.2	0.09
Bedroom 2 (Small bedroom, 3rd floor) - 6.9 m^2	0.11	0.07
Bathroom 1 (2nd floor) - 5 m^2	0.06	0.12

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Bathroom 2 (3rd floor)* - 3.1 m^2	0.12	0.07
Total	1.63	1.7

* In these zones no PLURAL will be applied. However, they are included in the table because they are part of the same dwelling.

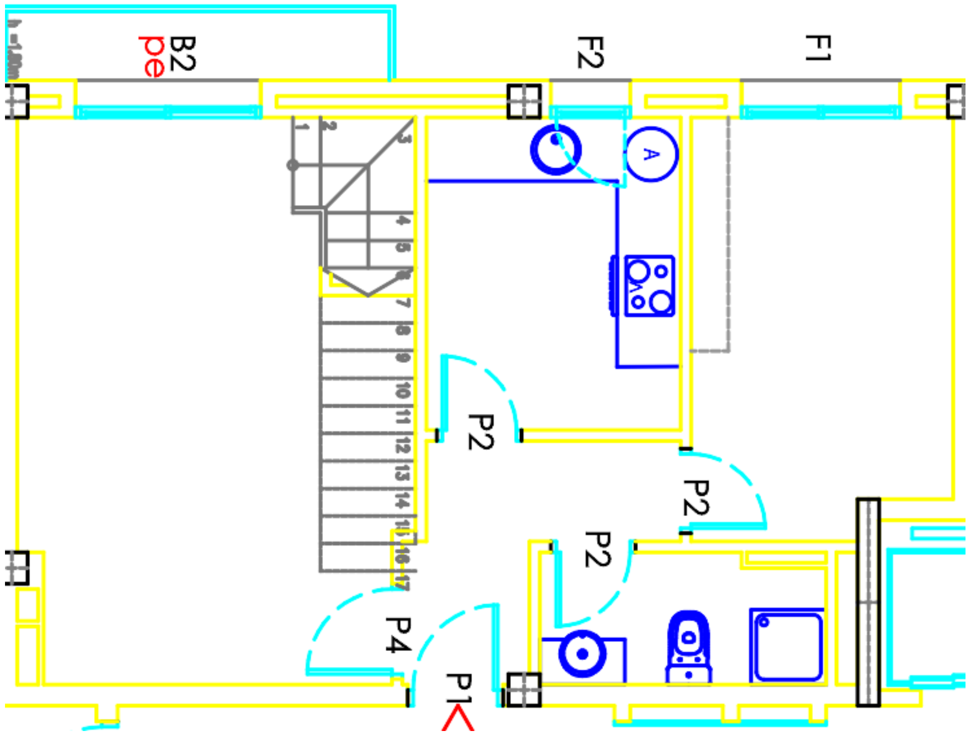

FIGURE 2.18: FLOOR PLAN OF THE BOTTOM FLOOR OF APARTMENT 3 MENTIONED IN **TABLE** 2.20

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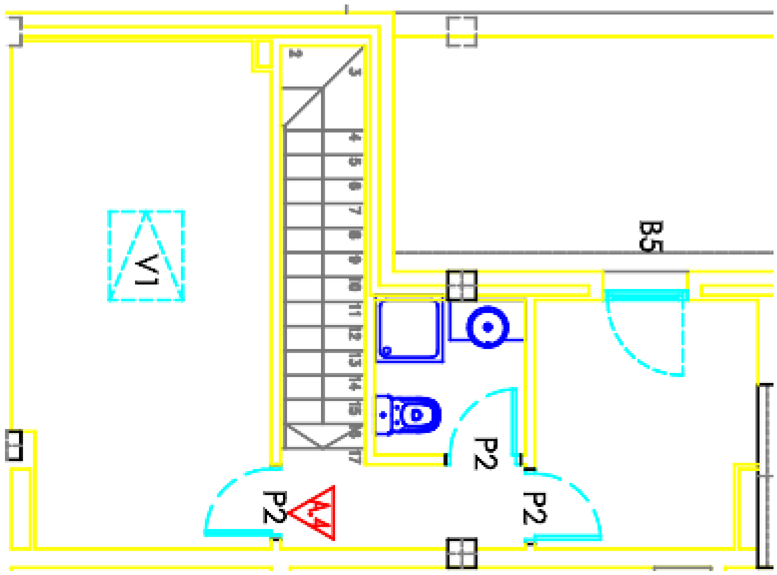

FIGURE 2.19: FLOOR PLAN OF THE TOP FLOOR OF APARTMENT 3 MENTIONED IN TABLE 2.20

2.3.3 *Cooling loads calculation*

Table 2.21, Table 2.22 & Table 2.23 provide the peak internal and solar gains for three representative dwellings and each of their zones for the Terrassa demo site that PLURAL will be applied. The values indicated are taken from simulation results and not via a sizing procedure.

TABLE 2.21: DOUBLE FRONTAGE APARTMENT GAINS

Apartment 1 – double frontage (3 occupant apartment, 59.5 m^2)	PLURAL renovation cooling load - kW			
Modelled as a single thermal zone	Internal gains	Solar gains	Infiltration – Ventilation gains	Transmission gains
Total	0.12	0.15	0.06	0.87

TABLE 2.22: TWO-BEDROOM APARTMENT ZONES GAINS

Apartment 2 – single frontage (3 occupant apartment, 50.1 m^2)	PLURAL renovation cooling load - kW			
	Internal gains	Solar gains	Infiltration – Ventilation gains	Transmission gains
Living room and Kitchen - 25.6 m^2	0.08	0.03	0.003	1.16
Bedroom 1 (Master bedroom) - 12.5 m^2	0.03	0.01	0.001	0.63
Bedroom 2 (Small bedroom) - 6.9 m^2	0.01	0.01	0.002	0.22
Bathroom – 5 m^2	0.0	0.0	0.0	0.0
Total	0.12	0.05	0.006	2.01

TABLE 2.23: DUPLEX APARTMENT ZONES GAINS

Apartment 3 – two floor (4 occupant apartment, 79.5 m^2)	PLURAL renovation cooling load - kW			
	Internal gains	Solar gains	Infiltration – Ventilation gains	Transmission gains
Living room and Kitchen (2nd floor) - 26.2 m^2	0.08	0.03	0.003	1.19
Common area (3rd floor)* - 28.3 m^2	0.13	0.06	0.22	1.14
Bedroom 1 (Master bedroom, 2nd floor) - 10 m^2	0.03	0.01	0.001	0.59
Bedroom 2 (Small bedroom, 2nd floor) - 6.9 m^2	0.02	0.008	0.0009	0.43
Bathroom 1 (2nd floor) - 5 m^2	0.0	0.0	0.0	0.0
Bathroom 2 (3rd floor) * - 3.1 m^2	0.0	0.0	0.0	0.0
Total	0.26	0.108	0.2249	3.35

* In these zones no PLURAL will be applied. However, they are included in the table because they are part of the same dwelling.

2.3.4 DHW profile

Regulatory profiles

The Domestic Hot Water (DHW) profile is displayed in .Figure 2.20 The same schedule for both the realistic and regulatory CTE [6] conditions was used for the simulations.

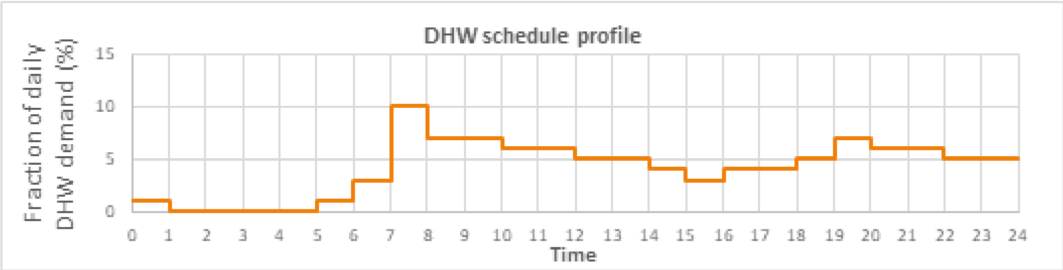

FIGURE 2.20: DHW PROFILE USED IN THE SPANISH DEMO CASE

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3 Final heating and cooling system selection for demonstration buildings

In this chapter the final heating and cooling systems selections of the demonstration buildings are realized based on the selection justifications and the sizing that were carried out in the previous chapters.

3.1 Greek demonstration building – VVV

The heat pump unit is usually selected in such a way, so that it can cover both the heating and cooling demands of a building. As already mentioned in the previous paragraphs, the calculated cooling loads for the VVV demonstration building exceed the corresponding heating loads (as often is the case in most of the Greek buildings, due to the country's climatic conditions), hence the sizing of the heat pump system was based on the cooling loads.

The overall dimensioning of the cooling and heating system was defined via the 4M software following the assumptions and calculation methods of the specific software. The number and capacity of the fan coils was defined, however due to the limited variety of fan coil units included on the software's library, it was not possible to select DAIKIN fan coil units during the calculations, but other similar types of fan coils which by extend differentiated a little bit the resulting size/capacity of the heat pumps. For this reason, it was decided to take into account the basic calculations provided by the 4M software and select the fan coil units for each room of the apartments, based on the demands of each room and by corresponding these demands/loads to specific DAIKIN fan coil models. Then, after having chosen the fan coil models for each room, the overall loads required in order to supply the selected fan coils for each apartment were defined, and thus, the capacity of the heat pumps was derived.

Another factor that was counted in for the selection of the fan coil models, were the actual dimensions of the units, since they should fit inside the SmartWall panels and be as compact as possible.

In this way, two different DAIKIN fan coil models were selected, one without casing which will be incorporated inside the SmartWall, and one with a casing which will be wall-mounted:

- FWXM10ATV3, is the concealed type FCU model that will be installed inside the SmartWall panels of the corresponding rooms, and
- FWXT20ATV3(C/CL), is the wall mounted type FCU which was selected because of its dimensions and will be installed on the existing walls of the kitchens' areas. These fan coils will be placed above the kitchens' window.

Both units are depicted in Figure 3.1.

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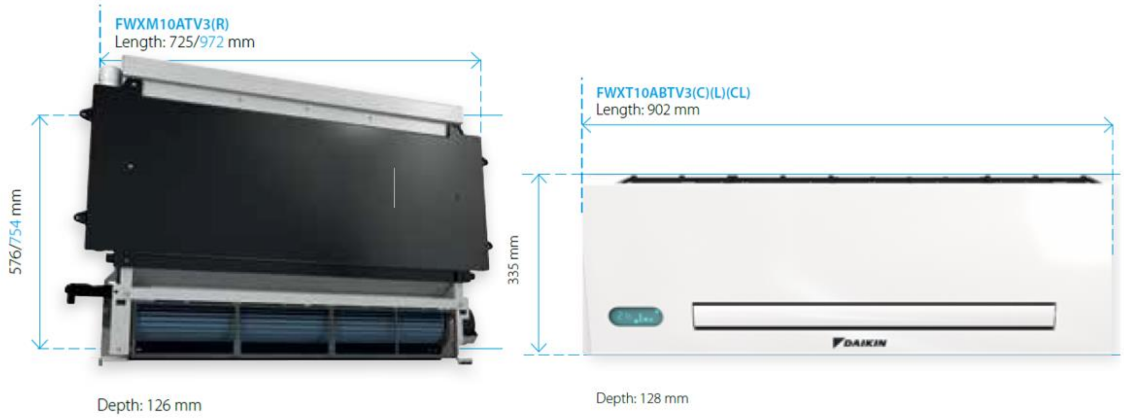

FIGURE 3.1: THE FWXM10ATV3 FAN COIL MODEL DURING THE ASSEMBLY OF ONE OF THE PROTOTYPES

In the following drawing (Figure 3.2) the proposed positioning of the fan coils is presented, as well as the different fan coil models.

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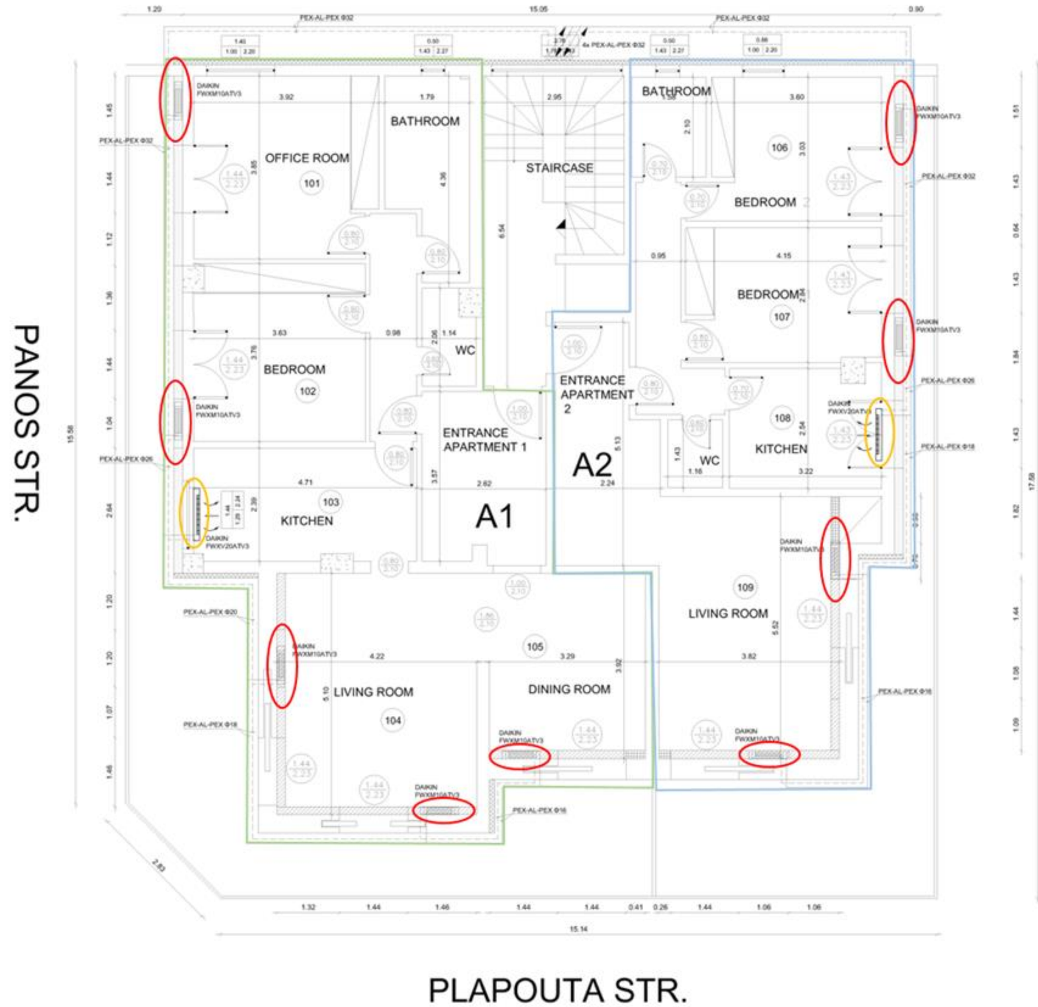

FIGURE 3.2: PROPOSED POSITIONING OF FAN COILS INSIDE THE APARTMENTS (YELLOW COLOR - FWXT20ATV3 MODEL, RED COLOR - FWXM10ATV3 MODEL)

FIGURE 3.3: THE FWXM10ATV3 FAN COIL MODEL DURING THE ASSEMBLY OF ONE OF THE PROTOTYPES

The size of the heat pumps was derived by summarizing the total heat/cool loads that would be required to supply the selected, for each apartment, fan coils. In addition, the type of the heat pump has been selected to be mono-block type due to the lack of space. Following the recommendations of the Technical Department of VVV Municipality, the heat pumps will be placed in the roof of the building, adjacent to the existing terrace room, facing northeast, while their piping route will be on the east facade wall, which will be covered by ETICS by VVV during 2nd Renovation Stage.

Any auxiliary equipment to heat pumps installation such as buffer tanks, electro valves, monitoring equipment etc., will be placed in the existing terrace room adjacent to the heat pumps. In the following drawing (Figure 3.4) the positioning of the heat pumps on the rooftop of the building is presented.

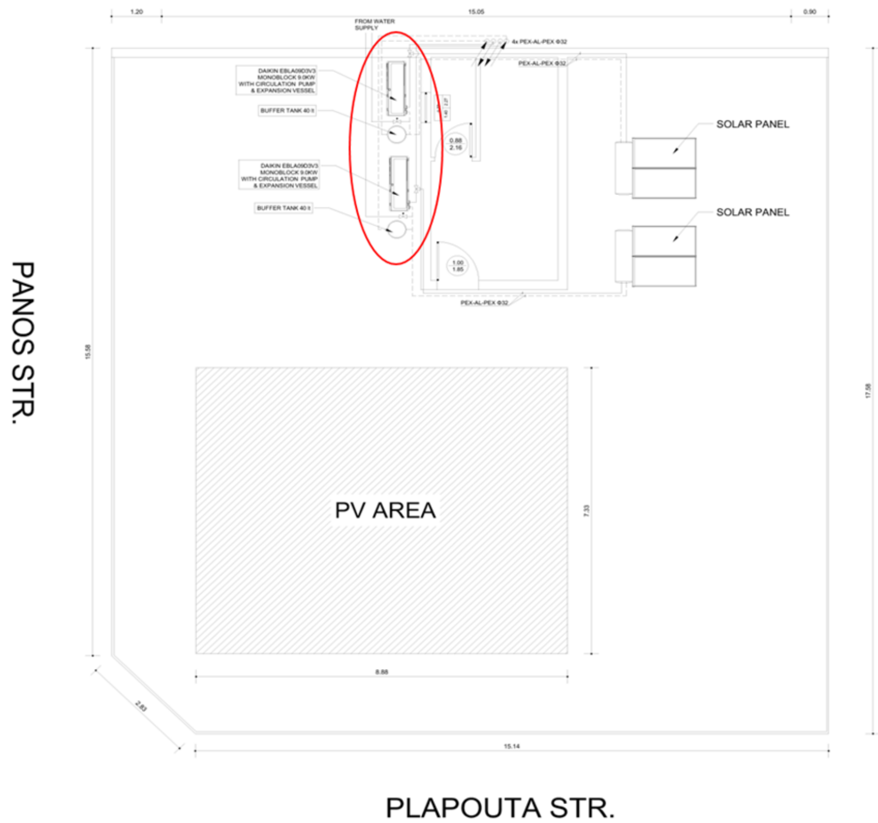

FIGURE 3.4: Heat Pumps Positioning On The Building's Rooftop

Therefore, the 4M software was mostly used to provide guidelines for the final selection of the heating and cooling system and to also, calculate the piping characteristics (length, diameter etc.) and quantities of materials needed for the final installation.

Some of the assumptions introduced in 4M software, for the calculation of the heating – cooling system capacity, were the following (more detailed assumptions and calculations are presented in the next chapter of this document and in the Annexes):

- Water temperature: 7°C
- Fan coil unit temperature difference: 5°C
- Dry bulb temperature: 26°C
- Wet bulb temperature: 18.5°C
- Type of piping: Multilayered pipes – Multiskin type
- Maximum water velocity: 0.6m/s
- Number of heat pumps: 2 (one for each apartment)
- Units: kW

- Fan coil's fan velocity: medium
- Pipes Insulation: Per KENAK regulation

TABLE 3.1: FAN COIL UNITS PER ROOM ALONG WITH THE LOADS PER EACH ROOM

Network section	Floor No.	Room No.	Room name	Sensible Space load (kW)	Latent Space load (kW)	FC type*	Output sensible load (kW)	Output latent load (kW)
7.8	1	4	Office Room-A1	0.559	0.204	FCU200	1.364	0.415
9.10	1	3	Bedroom1-A1	0.608	0.193	FCU200	1.364	0.415
11.12	1	2	Kitchen-A1	1.758	0.618	FCU300	2.324	0.752
15.16	1	1	Living Room-A1	0.606	0.206	FCU200	1.364	0.415
18.19	1	1	Living Room-A1	0.606	0.206	FCU200	1.364	0.415
22.23	1	1	Living Room-A1	0.606	0.206	FCU200	1.364	0.415
29.30	1	8	Bedroom2-A2	0.624	0.172	FCU200	1.364	0.415
31.32	1	7	Bedroom1-A2	0.413	0.179	FCU200	1.364	0.415
33.34	1	6	Kitchen-A2	1.693	0.545	FCU300	2.324	0.752
36.37	1	5	Living Room-A2	0.680	0.205	FCU200	1.364	0.415
39.40	1	5	Living Room-A2	0.680	0.205	FCU200	1.364	0.415

**The specific fan coil units refer to another provider and not to DAIKIN, as DAIKIN as a manufacturer was not included in the software's library list.*

Table 3.1 was used to define the loads per each room and thus to define the fan coil units and capacities needed for each room. The selection of the heat pump was based in these total loads and especially on the calculated cooling loads. The total cooling loads are corresponding to approximately 11.77 kW for both apartments, and this was also the resulted capacity of the required cooling unit according to the 4M software. These 11.77kW are corresponding to one heat pump system for both apartments, however as the request of VVV Municipality (see also *Deliverable 2.1 "Detailed architectural and* *structural design"* for the related requirements/limitations) was to keep the autonomy of each apartment in terms of heating, cooling, DHW production and PV production, it was decided to use two heat pumps, one for each apartment. As a result, A1 apartment has a total load of approximately 6.4kW and A2 apartment a total load of approximately 5.4kW, as was estimated by 4M software. The highest loads were calculated for the kitchens of the apartments, as there are many appliances operating inside those spaces which result in increased heat gains. However, not all kitchen appliances are operating simultaneously and this high cooling load calculated by 4M software is the peak load, which apparently is occurring rarely.

The selection of the heat pump's capacity and model was therefore based on the following:

1. The above mentioned calculated by 4M software, loads for each apartment.
2. The selected fan coil's capacities. Each room of the apartments will be heated or cooled by a fan coil of 2.12kW cooling capacity and 2.21kW heating capacity (FWXM10ATV3), whereas the kitchens will be conditioned by a fan coil of 2.12kW cooling capacity and a 2.62kW heating capacity (FWXT20ATV3(C/CL)). (Heating and cooling capacities refer to the high fan speed).
3. It was decided to use mono-block type heat pumps due to the lack of space.
4. The selected heat pump should be also capable of supporting the DHW production, as a backup unit, when the available heat load produced by the solar collectors is not enough to cover the building's needs.

Taking into consideration all the aforementioned data, the smallest available capacity in the mono block category on the Daikin's product catalogue, which could also cover the calculated heating and cooling loads, was proved to be the EBLA09D3V3 model, with an overall cooling capacity of 9.10kW and a heating capacity of 9kW.

FIGURE 3.5:PICTURE OF THE HEAT PUMP

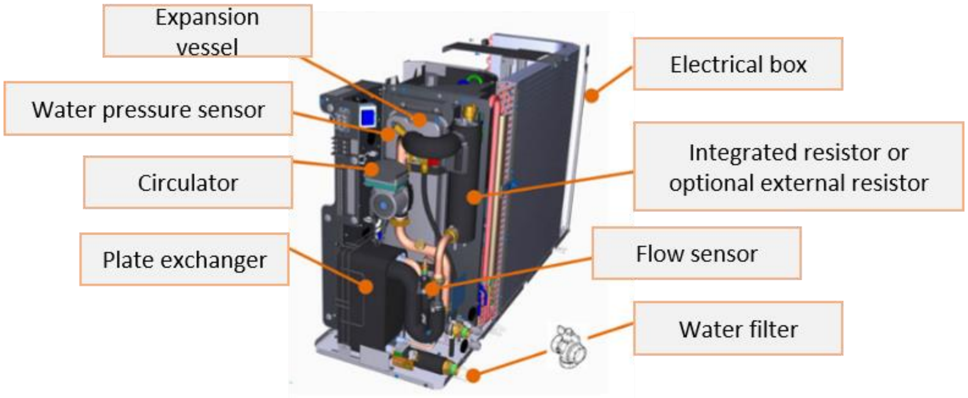

FIGURE 3.6: Heat Pump Schematic of various components

As a concluding point, the heat pump will support the production of domestic hot water (DHW), when the available heat load produced by the solar collectors is not enough, and a second support will be provided by an electrical resistance, thus composing a triple energy system for the DHW production.

Table 3.2 presents a summary of the devices selected to constitute the heating and cooling system of the renovated area of Voula building:

TABLE 3.2: DAIKIN FAN COILS & HEAT PUMP SELECTED FOR VOULA DEMO SITE

DAIKIN SYSTEM	Type/Model	Quantity
FANCOILS	FWXM10ATV3	9
	FWXT20ATV3(C/CL)	2
HEAT PUMPS (mono-block Single-Phase)	EBLA09D3V3	2

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Technical specifications				EBLA09D3V3	EBLA11D3V3	EBLA14D3V3	EBLA16D3V3
Heating capacity	Nom.		kW	9.37 (1) / 9.00 (2)	10.6 (1) / 9.82 (2)	12.0 (1) / 12.5 (2)	16.0 (1) / 16.0 (2)
Cooling capacity	Nom.		kW	9.35 (3) / 9.10 (4)	11.6 (3) / 11.5 (4)	12.8 (3) / 12.7 (4)	14.0 (3) / 15.3 (4)
Heater capacity	Step 1		kW	3			
Power input	Cooling	Nom.	kW	2.79 (3) / 1.71 (4)	3.56 (3) / 2.17 (4)	4.06 (3) / 2.51 (4)	4.58 (3) / 3.24 (4)
	Heating	Nom.	kW	1.91 (1) / 2.43 (2)	2.18 (1) / 2.68 (2)	2.46 (1) / 3.42 (2)	3.53 (1) / 4.56 (2)
COP				4.91 (1) / 3.71 (2)	4.83 (1) / 3.66 (2)	4.87 (1) / 3.64 (2)	4.53 (1) / 3.51 (2)
EER				3.35 (3) / 5.34 (4)	3.26 (3) / 5.31 (4)	3.16 (3) / 5.04 (4)	3.06 (3) / 4.74 (4)
SEER				5.62 (5)	5.79 (5)	5.71 (5)	5.59 (5)
Casing	Colour			Silver			
	Material			Polyester painted galvanised steel plate			

(1)Condition: Ta DB/WB 7°C/6°C - LWC 35°C (DT = 5°C) |
(2)Condition: Ta DB/WB 7°C/6°C - LWC 45°C (Dt=5°C) |
(3)Cooling: EW 12°C; LW 7°C; ambient conditions: 35°CDB |
(4)Cooling: EW 23°C; LW 18°C; ambient conditions: 35°CDB |

FIGURE 3.7 TECHNICAL MAIN SPECIFICATIONS OF EBLA09D3V3 DAIKIN'S HEAT PUMP

The heat pump model selected utilizes R32 as a refrigerant which is a non-toxic substance and with low GWP and zero ODP. More detailed datasheets and specifications of the heat pump and the fan coils, are included in the Annex 6.3.1.

3.2 Czech demonstration building – Kasava

The demo building of Kasava was simulated in Trnsys under realistic boundary conditions and with a model for a real heating system. An air-to-water heat pump with a combi storage was modelled and considered as main system for DHW preparation and space heating. Standard control configuration was set and a set-point room temperature of 21.0 °C was assumed. Internal gains were assumed according to benchmark numbers of the latest study of Czech Statistical Office (see section 2.2.1). Decentralized ventilation units with energy recovery were considered according to the actual ventilation plans (see Figure 2.5). For more details about the ventilation system, additional info can be found in the D2.3 – "Ventilation systems selected for each demo site". DHW load profile was assumed according to chapter 2.2.3.

Figure 3.8 shows the simulated heat pump condenser power depending on the ambient temperature.

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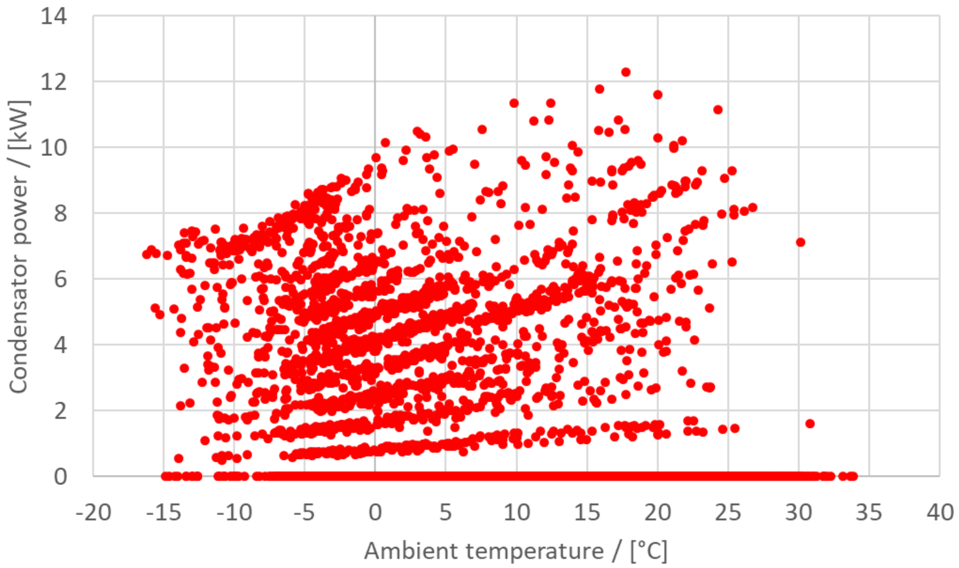

FIGURE 3.8: SIMULATED HEAT PUMP CONDENSER POWER VERSUS AMBIENT TEMPERATURE (HOURLY VALUES) FOR THE REAL DEMO BUILDING OF KASAVA – THE HEAT PUMP IS USED FOR SPACE HEATING AND DHW PREPARATION

Based on the simulation of the condenser power, the Daikin heat pump ERLA11 was chosen for the Kasava demo. The HP matches well the simulated maximum power demand of the condenser (Figure 3.9).

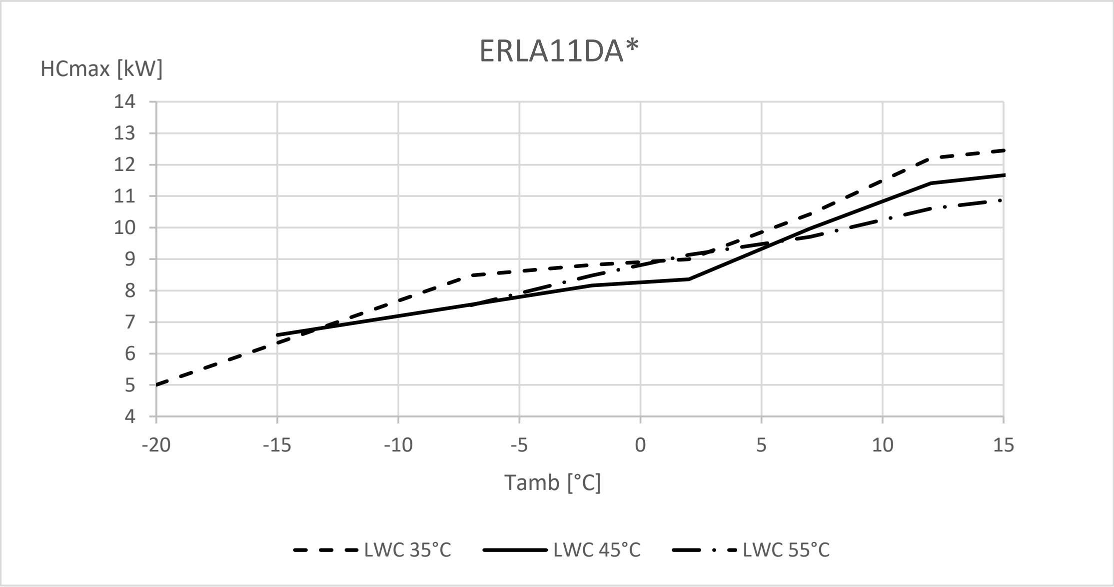

FIGURE 3.9: HEAT PUMP CONDENSER POWER VERSUS AMBIENT TEMPERATURE OF THE DAIKIN HEAT PUMP ERLA11DA THAT WAS CHOSEN FOR THE KASAVA DEMO (SOURCE: DAIKIN ALTHERMA LOW TEMPERATURE SPLIT – TECHNICAL DATA)

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The ERLA heat pump is a split heat pump with an outdoor and an indoor unit (Figure 3.10). Technical specifications of the HP are as follows:

- Units:
  - Outdoor unit ERLA11DW1
  - Indoor unit EBBH11D6V
- Nominal heating capacity: 10.6 kW @ A7/W35
- Coefficient of performance: 4.83 @ A7/W35
- Operation range: condenser temperature max. 60 °C above -7 °C ambient air temperature
- Water flow rate: 1760 L/h
- Heating only (no cooling function)
- Three phase, 400 V

FIGURE 3.10: OUTDOOR UNIT (LEFT) AND INDOOR UNIT (RIGHT) OF THE DAIKIN SPLIT HEAT PUMP FOR THE KASAVA DEMO

The split type is suitable for temperature below zero as the water piping runs only indoors which means no freezing risk of water exists. The heat pump model selected utilizes R32 as a refrigerant which is a non-toxic substance and with low GWP and zero ODP. Full specifications of the split type heat pump (ERLA11DW1 + EBBH11D6V) are presented in Annex 6.3.2.

As the HP should be used to minimize the purchase from the electric grid, a power control unit is chosen that allows for reducing the electric energy consumption of the compressor. The reduction can be used if the generation of heat is not critical with respect to time. A Daikin Demand PCB (product EKRP1AHTA) with five power steps (one of them 100 % power) will be used. The minimum compressor speed is 30%.

3.3 Spanish demonstration building – Terrassa

As described in section 1.2.3, the building in Terrassa will be equipped with the AHU unit of the eAHC system that will be integrated in the prefabricated façade. The unit provides ventilation with an active heat recovery system which means it con provide some heating and some cooling, but not fully cover the heating and cooling demands of each apartment. Basic heating and cooling systems will be the ones already existing and repaired or replaced where needed.

For this reason, the only analysis that can be made for this demo in respect with the heating and cooling system selection is to describe what part of the heating and cooling demands the AHU units will cover in an average apartment of the Terrassa building. Given the fact that the apartments of the building are generally small their heating loads as described in 2.2.3 will be after renovation in the range of 1 kW to 3.3 kW. Depending on the number of the AHUs that are going to be installed, the eAHC system can cover a significant part of the total heating and less of the cooling demand and contribute to energy savings.

The basic specifications of the ventilation unit of the eAHC panel are provide in Table 3.3.

TABLE 3.3: OVERVIEW OF BASIC SPECIFICAITONS OF VENTILATION UNIT FOR EAHC PANEL

Parameter	Value	unit
Manufacturer	Recuair	[-]
Air flow		
Max. air flow	90	m3/h
Min. air flow	20	m3/h
Efficiency and performance		
Heat recovery efficiency (min.)	85	%
COP range	1.5 - 10	[-]
EER range	0.9 - 1.6	[-]
Heating power	600	W
Cooling power	200	W

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4 Drawings, calculations & simulations – Results & validation

4.1 Greek demonstration building – VVV

The heating and cooling system selection for the VVV demonstration building was based on the heating and cooling loads of the renovated state of the building. The selected system was presented in Chapter 3.2 of the current document. The heating and cooling loads of the two apartments under renovation were presented in Chapter 2.1 along with the DHW needs.

The fan coils calculation section of the 4M software has produced also the tables including the appropriate type and dimensions of piping network which is going to be installed in Voula building, after taking into consideration the requirements and limitations already set in *D2.1 "Architectural and structural design of PnU kits"*. As was presented in *chapter 6.1 "Architectural Design"* of the *D2.1 "Architectural and structural design of PnU kits"*, the main HVAC systems will be installed in the roof of the building adjacent to the terrace room facing northeast, while the solar panels will be installed at the southeast side of the building.

One of the most significant issues realized during the building survey at the early stages of the project, as thoroughly explained in *Deliverable D.7.1 – "Preliminary Design"*, was the fact that the existing pipework supposed to be used for the SmartWall PnU kits installation, was deteriorated due to aging, therefore useless. To anticipate this major problem, was decided the installation of a new piping system, under the following conditions and requirements set by VVV Municipality:

- Install all HVAC systems in the roof at the locations indicated by the Technical Department of VVV Municipality;
- Use the existing pipework routing at the east side of the building which provides access for maintenance and will be covered by ETICS (VVV Municipality);
- The new piping system will be routed at the wall of the ground floor attached to the balcony slab of the 1st floor (below it). Holes on suitable locations at the balcony slab of the 1st floor will be drilled allowing free access of the pipework at the balcony of the 1st floor, adjacent to floor's façade wall.
- The new routing at the ground floor wall will be covered by ETICS and skirting on its top (for maintenance purposes), in order to insulate the pipework and match the aesthetics of the building.
- The new piping system will be connected inside the frame's void of SmartWall panels with appropriate fittings.

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- Each apartment will use its own main HVAC piping system, therefore two piping limbs will be installed:

a. For A1 apartment: pipe's routing starts from the roof facing downwards on east façade wall and just below the ground floor balcony turns on the north façade's wall, crossing all over it, ends at approximately on the middle of the west façade, just below the dining room;

b. Similarly, for A2 apartment the pipe's routing starts from the roof facing downwards on east façade wall and just below the ground floor balcony, turns on the south façade's wall, crossing all over and ends below the living room on the west façade.

For the exterior piping system is proposed the by COMAP Multiskin 4[4] tubing system consisting by multi-layer tubes (combined layers of cross-linked polyethylene PER or PE-X and aluminum) and of the same type metal grip fittings (Figure 4.1).

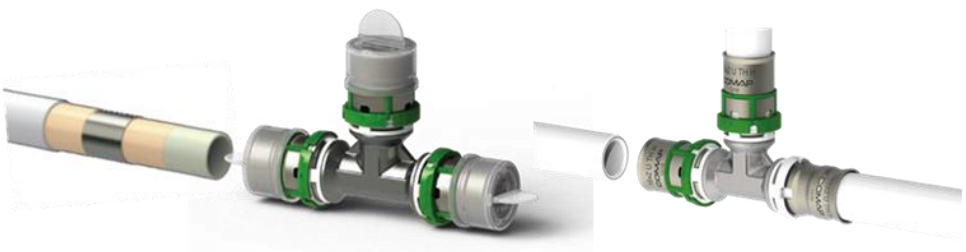

FIGURE 4.1: COMAP – MULTISKIN 4 SYSTEM – TUBE & METAL GRIP FITTING

Wherever it is needed, the pipes and all exposed HVAC components will be further insulated with AF/ArmaFlex[5] or equivalent material to prevent heat loss.

For domestic hot water supply for both of the apartments will be used the same piping routing methodology. Starting from the solar panels on the building's roof towards to the east façade wall of the building, and via the access channel on ETICS installation, will end in the small loft of each apartment, which is located on the top of the bathroom ceiling and is currently installed the electric boiler for domestic hot water production. As already mentioned, for the DHW supply, the internal existing pipework of the building will be used as its condition is in a good state, and all the related calculations concerning the hot water piping will be presented in *D2.5 "Report with design and operational features of toolbox"*.

[4] https://www.comap-solutions.com/sites/international/files/field/media/files/01023_2018-10_en_guide_technique_multicouche.pdf

[5] https://local.armacell.com/fileadmin/cms/downloads/product-catalogues/en/AFArmaflex_SpecialPage_EN.pdf

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All hydraulic works will be executed aiming to least possible damage of the existing building's structure elements and in accordance with the provisions of the current Greek "Regulation of Internal Plumbing Installations"[6].

For the definition of the diameter and length of the heating and cooling piping, the 4M software was used. The sectioning of the piping network, along with the piping length of each section has followed the geometry of the building and was based on the building's drawings and the on-site realized measurements. In addition, the piping length for each segment of the network includes the piping for the supply and return of the water. In the following tables the assumptions and results of the 4M software regarding the piping network along with the loads of the fan coils in each space of the apartments are presented. These tables are also used to estimate the quantity and type of the auxiliary hydraulic connections or accessories that will be required.

The data considered for the piping network are the following:

TABLE 4.1: PIPING NETWORK DATA/ASSUMPTIONS

Water Temperature (°C)	7
Temperature Difference occurred in units FC (°C)	5
Main Tube type	Multilayer MULTISKIN with insulation 9mm
Roughness Coefficient of main tube (μm)	7
Secondary Tube type	Multilayer MULTISKIN with insulation 9mm
Roughness Coefficient of secondary tube (μm)	7
Unit system	KWatt

The results associated with the network calculations are presented in a table with the following columns:

- Network segment
- Segment length (m)
- FCU load (kcal/h or w or kBTU/h)
- Temperature difference Δt (°C)

[6] https://www.elinyae.gr/sites/default/files/2019-07/21a_91.1149587136620.pdf

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- Water supply (m3/h)
- Tube diameter (mm)
- Speed of water (m/s)
- Overall resistance of components Σζ
- Friction of components (mYΣ)
- Friction of tubes (mYΣ)
- Overall segment friction (mYΣ)

Table 4.2: Calculations Associated With The Fan Coils Piping Network

Network segment	Tube/segment length (m)	Load FC (KW)	Temperature difference (°C)	Water supply (m^3/h)	Tube type	Tube diameter (mm)	Water speed (m/s)	Σζ	Friction. Εξ/FC (mYΣ)	Tube Frictions(mYΣ)	Overall Frictions (mYΣ)
1.2	0.5			1.098	M	32	0.574	1.300	0.022	0.010	0.032
2.3	13			1.098	M	32	0.574	1.300	0.022	0.254	0.276
3.4	14			1.098	M	32	0.574	2.500	0.042	0.274	0.316
4.5	0.2			1.098	M	32	0.574	1.300	0.022	0.004	0.026
5.6	0.7			1.098	M	32	0.574	1.300	0.022	0.014	0.036
6.7	2			1.098	M	32	0.574	2.000	0.034	0.039	0.073
7.8	1	0.763	5	0.131	M	16	0.322	1.500	0.183	0.020	0.203
7.9	14			0.967	M	32	0.506	2.000	0.026	0.219	0.246
9.10	1	0.801	5	0.138	M	16	0.338	1.500	0.200	0.021	0.221
9.11	1.6			0.829	M	26	0.733	2.000	0.055	0.067	0.122
11.12	1	2.376	5	0.409	M	16	1.004	1.500	1.564	0.139	1.702
11.13	4.7			0.420	M	20	0.580	1.300	0.022	0.174	0.196
13.14	3.5			0.420	M	20	0.580	1.300	0.022	0.129	0.152

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14.15	4.5			0.420	M	20	0.580	2.000	0.034	0.166	0.200
15.16	1.6	0.812	5	0.140	M	16	0.343	1.500	0.204	0.035	0.239
15.17	7			0.280	M	18	0.505	1.300	0.017	0.242	0.259
17.18	8.5			0.280	M	18	0.505	2.000	0.026	0.293	0.319
18.19	1.6	0.812	5	0.140	M	16	0.343	1.500	0.204	0.035	0.239
18.20	2.7			0.140	M	16	0.344	1.300	0.008	0.059	0.067
20.21	2.4			0.140	M	16	0.344	1.300	0.008	0.052	0.060
21.22	1.7			0.140	M	16	0.344	1.300	0.008	0.037	0.045
22.23	1.4	0.812	5	0.140	M	16	0.343	1.500	0.204	0.030	0.235
1.24	0.5			0.928	M	32	0.486	1.300	0.016	0.007	0.023
24.25	15			0.928	M	32	0.486	1.300	0.016	0.219	0.235
25.26	14.20			0.928	M	32	0.486	1.300	0.016	0.207	0.223
26.27	0.20			0.928	M	32	0.486	1.300	0.016	0.003	0.019
27.28	0.70			0.928	M	32	0.486	1.300	0.016	0.010	0.026
28.29	1.90			0.928	M	32	0.486	2.000	0.024	0.028	0.052
29.30	1.40	0.796	5	0.137	M	16	0.336	1.500	0.197	0.029	0.227
29.31	10.40			0.791	M	32	0.414	2.000	0.017	0.115	0.132
31.32	1.40	0.592	5	0.102	M	16	0.250	1.500	0.117	0.018	0.135
31.33	3.40			0.689	M	26	0.609	2.000	0.038	0.103	0.141
33.34	1.40	2.238	5	0.385	M	16	0.945	1.500	1.407	0.175	1.582

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33.35	5.10			0.304	M	18	0.549	1.300	0.020	0.203	0.223
35.36	1.85			0.304	M	18	0.549	3.300	0.051	0.074	0.124
36.37	2.20	0.885	5	0.152	M	16	0.374	1.500	0.238	0.055	0.293
36.38	9.60			0.152	M	16	0.373	1.300	0.009	0.241	0.250
38.39	5.55			0.152	M	16	0.373	1.300	0.009	0.139	0.148
39.40	2.55	0.885	5	0.152	M	16	0.374	1.500	0.238	0.064	0.302

TABLE 4.3: FAN COIL UNITS CALCULATION

Network section	Conditioned space	Sensible Space load (kW)	Latent Space load (kW)	Supply water temperature (ºC)	Temperature Difference	Water Supply	FCU type	FC fan speed	Output sensible load (kW)	Output latent load (kW)
1.2						1.098				
2.3						1.098				
3.4						1.098				
4.5						1.098				
5.6						1.098				
6.7						1.098				
7.8	1.4	0.559	0.204	7	5	0.131	FCU200	2	1.364	0.415
7.9						0.967				
9.10	1.3	0.608	0.193	7	5	0.138	FCU200	2	1.364	0.415

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9.11						0.829				
11.12	1.2	1.758	0.618	7	5	0.409	FCU300	1	2.324	0.752
11.13						0.420				
13.14						0.420				
14.15						0.420				
15.16	1.1	0.606	0.206	7	5	0.140	FCU200	2	1.364	0.415
15.17						0.280				
17.18						0.280				
18.19	1.1	0.606	0.206	7	5	0.140	FCU200	2	1.364	0.415
18.20						0.140				
20.21						0.140				
21.22						0.140				
22.23	1.1	0.606	0.206	7	5	0.140	FCU200	2	1.364	0.415
1.24						0.928				
24.25						0.928				
25.26						0.928				
26.27						0.928				
27.28						0.928				
28.29						0.928				

29.30	1.8	0.624	0.172	7	5	0.137	FCU200	2	1.364	0.415
29.31						0.791				
31.32	1.7	0.413	0.179	7	5	0.102	FCU200	2	1.364	0.415
31.33						0.689				
33.34	1.6	1.693	0.545	7	5	0.385	FCU300	1	2.324	0.752
33.35						0.304				
35.36						0.304				
36.37	1.5	0.680	0.205	7	5	0.152	FCU200	2	1.364	0.415
36.38						0.152				
38.39						0.152				
39.40	1.5	0.680	0.205	7	5	0.152	FCU200	2	1.364	0.415

TABLE 4.4: FAN COIL UNITS PER EACH ROOM

Network section	Floor No.	Room No.	Room name	Sensible Space load (kW)	Latent Space load (kW)	FC type*	Output sensible load (kW)	Output latent load (kW)
7.8	1	4	Office Room-A1	0.559	0.204	FCU200	1.364	0.415
9.10	1	3	Bedroom1-A1	0.608	0.193	FCU200	1.364	0.415

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11.12	1	2	Kitchen-A1	1.758	0.618	FCU300	2.324	0.752
15.16	1	1	Living Room-A1	0.606	0.206	FCU200	1.364	0.415
18.19	1	1	Living Room-A1	0.606	0.206	FCU200	1.364	0.415
22.23	1	1	Living Room-A1	0.606	0.206	FCU200	1.364	0.415
29.30	1	8	Bedroom2-A2	0.624	0.172	FCU200	1.364	0.415
31.32	1	7	Bedroom1-A2	0.413	0.179	FCU200	1.364	0.415
33.34	1	6	Kitchen-A2	1.693	0.545	FCU300	2.324	0.752
36.37	1	5	Living Room-A2	0.680	0.205	FCU200	1.364	0.415
39.40	1	5	Living Room-A2	0.680	0.205	FCU200	1.364	0.415

TABLE 4.5: CALCULATION OF COOLING SYSTEM

Cooling Load (KWatt)	11.772
Heterochronism	1
Required Load	11.772
Cooling System Type selected	N/A
Outdoor Temperature (°C)	N/A
Departure Temperature (°C)	N/A
Collector Catering tube diameter	N/A
Cooling System Capacity (l)	N/A

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TABLE 4.6: SAFETY SYSTEMS CALCULATION

Closed Expansion Tank selection	
Water supply temperature tv (°C)	7
Water Return temperature tr (°C)	12
Average Operating Temperature tm = (tv+tr)/2 (°C)	9.5
Static Installation Pressure PA (bar)	
Final Pressure Installation PE = PA + 0.7 (bar)	
Final coefficient Af	0.0004
Water Content in the system Vs (l)	80.98
Water Expansion VA = Af x Vs (l)	0.03
Minimum Expansion Tank Volume VN=(PE+1)xVA/(PE-PA)(l)	0.00

As was already mentioned in the previous paragraphs, the capacity of the cooling system which should be selected, should be around 11.77kW for both apartments, according to the 4M software. Last but not least, the quantities of the auxiliaries and accessories needed for the piping network installation of the heating/cooling system, were calculated by the software as a preliminary approach. However, these quantities were slightly altered in such way to also include any wastage or unpredicted materials, whereas the exact quantities and any other accessories that were not foreseen at this stage and that will be finally required, will be determined and verified again before the final design stage of *Task 2.6.1.* and the final installation of the PnU kit under *Task 7.4 "Installation of PLURAL system in Voula – Athens (Greece) real demo case"*.

TABLE 4.7: PRELIMINARY ESTIMATION OF ACCESSORIES/MATERIALS QUANTITIES

Tube Diameter	Length/Quantities
MULTISKIN piping of 16mm diameter with 9mm insulation	57.75

MULTISKIN piping of 18mm diameter with 9mm insulation	33.67
MULTISKIN piping of 20mm diameter with 9mm insulation	19.05
MULTISKIN piping of 26mm diameter with 9mm insulation	7.50
MULTISKIN piping of 32mm diameter with 9mm insulation	130.95
FCU type	Quantity
FC DAIKIN – FWXM10ATV3	9 pieces
FC DAIKIN – FWXT20ATV3(C/CL)	2 pieces
Other components	Quantity
Cooling system/Heat Pump	2 pieces
Circulator	2 pieces
Circulator	2 pieces
Securing	2 pieces
Accessories	Quantity
Other accessories	To be defined
Pipe shrinkers	12
90° degree angle	20
T shape - 90° degree angle	12
Spigots	15

In the following pages the drawings of the routing of the piping for the heating, cooling and DHW systems are presented for Voula demo case.

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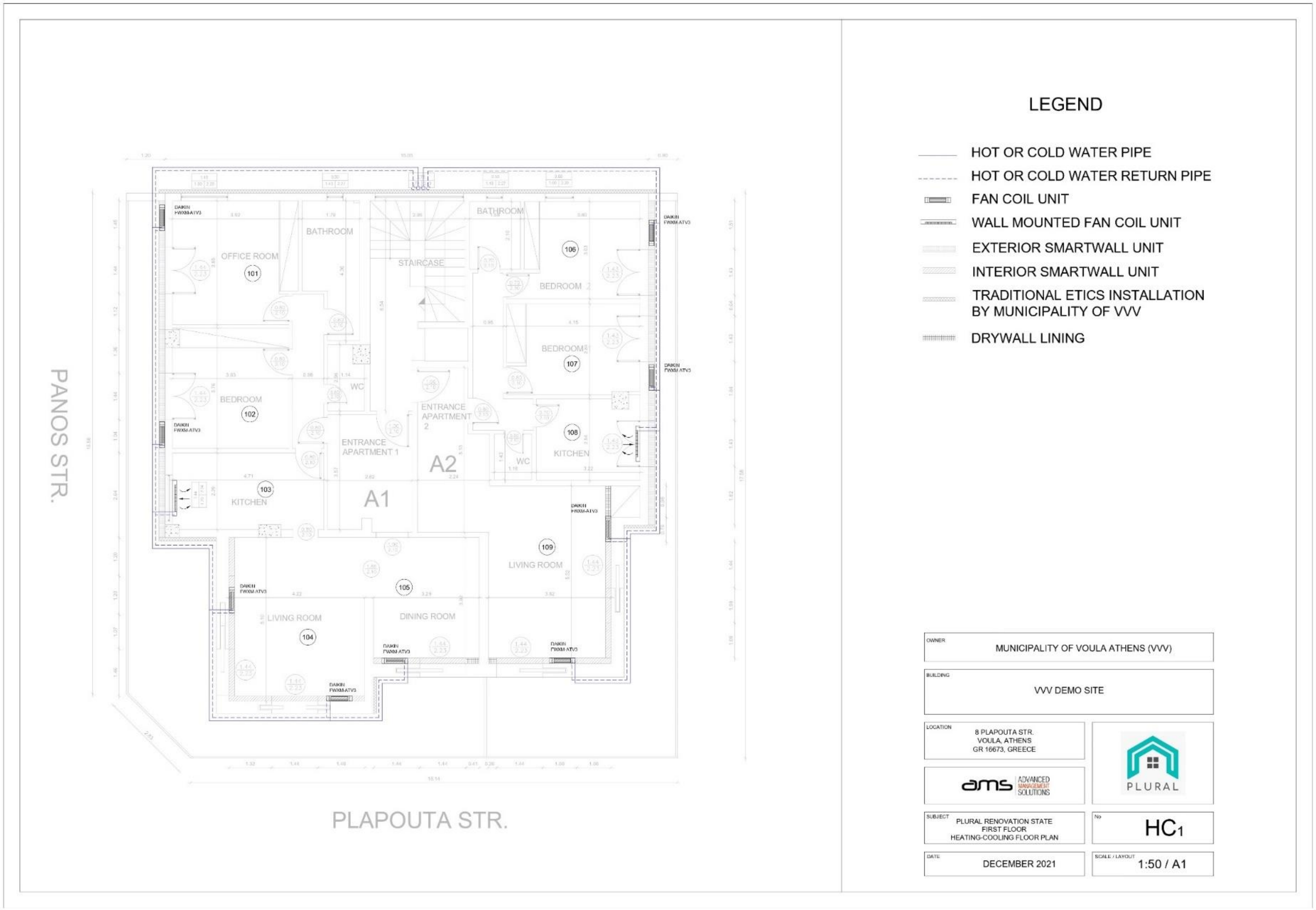
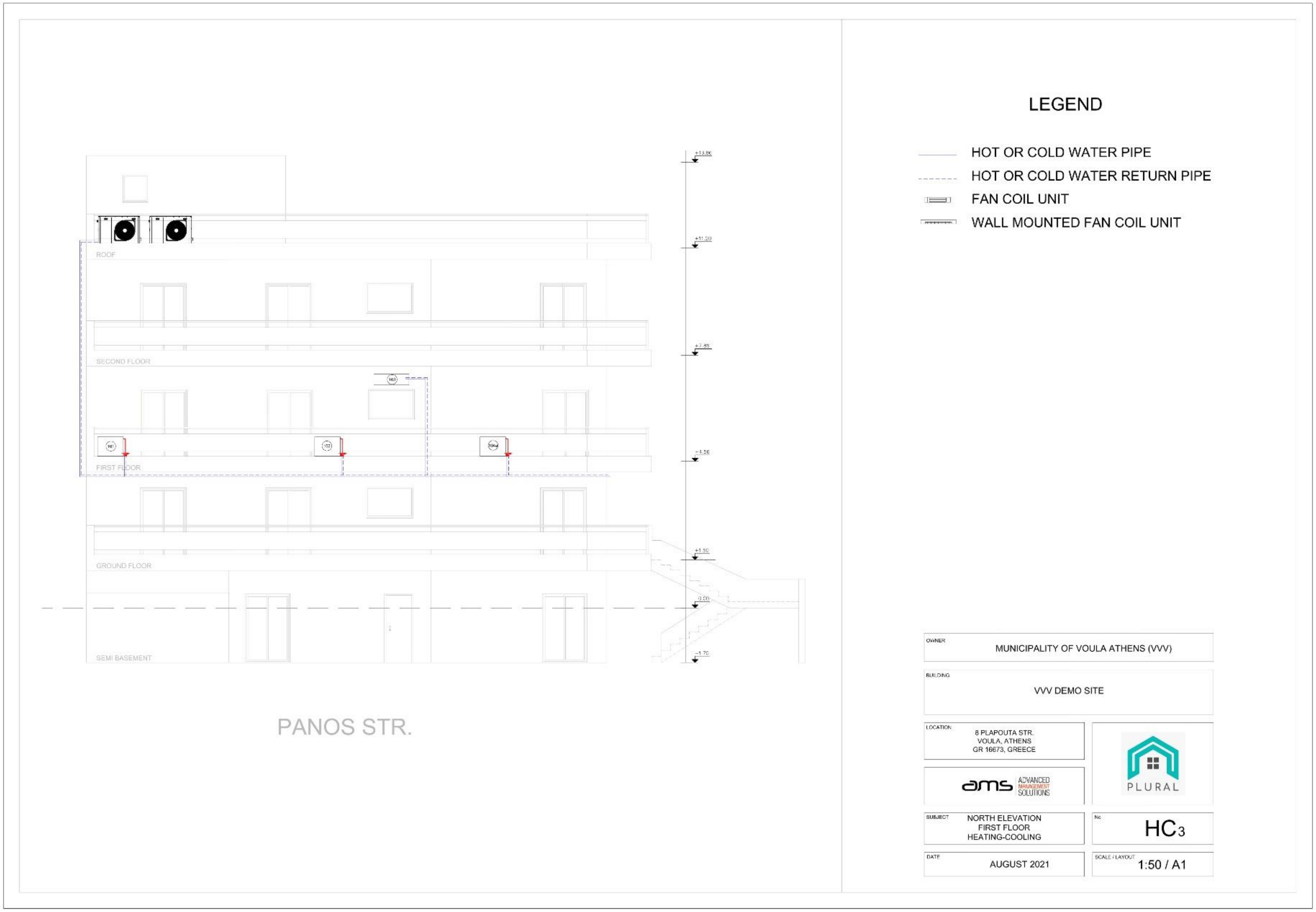
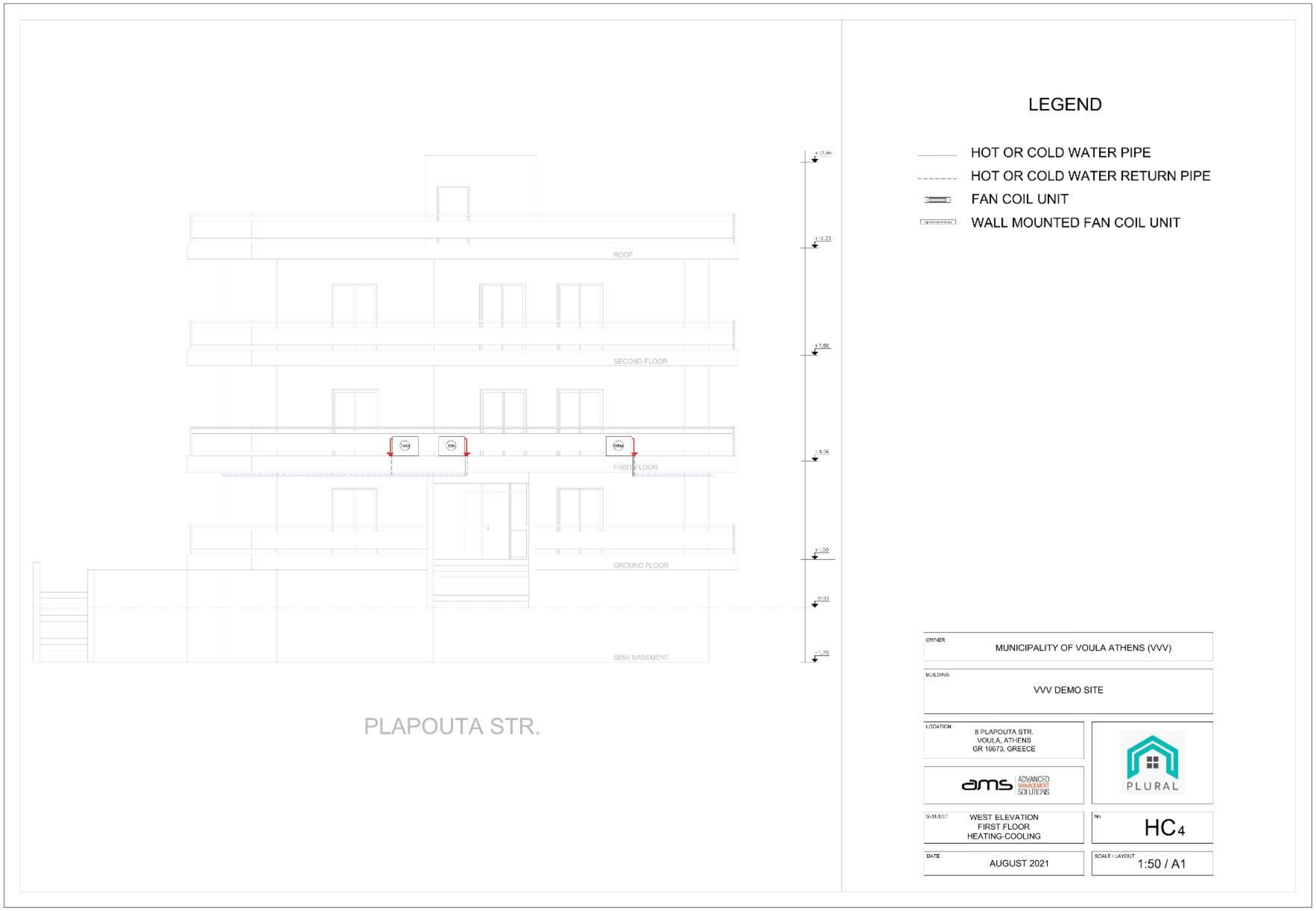

LEGEND
HOT OR COLD WATER PIPE
HOT OR COLD WATER RETURN PIPE
FAN COIL UNIT
WALL MOUNTED FAN COIL UNIT
EXTERIOR SMARTWALL UNIT
INTERIOR SMARTWALL UNIT
TRADITIONAL ETICS INSTALLATION BY MUNICIPALITY OF VVV
DRYWALL LINING
PANOS STR.
PLAPOUTA STR.
OFFICE ROOM
BATHROOM
STAIRCASE
BEDROOM
KITCHEN
WC
ENTRANCE APARTMENT 1
ENTRANCE APARTMENT 2
A1
A2
LIVING ROOM
DINING ROOM
OWNER
MUNICIPALITY OF VOULA ATHENS (VVV)
BUILDING
VVV DEMO SITE
LOCATION
8 PLAPOUTA STR.
VOULA, ATHENS
GR 16673, GREECE
ams ADVANCED MANAGEMENT SOLUTIONS
PLURAL
SUBJECT
PLURAL RENOVATION STATE
FIRST FLOOR
HEATING-COOLING FLOOR PLAN
No
HC1
DATE
DECEMBER 2021
SCALE / LAYOUT
1:50 / A1



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958218



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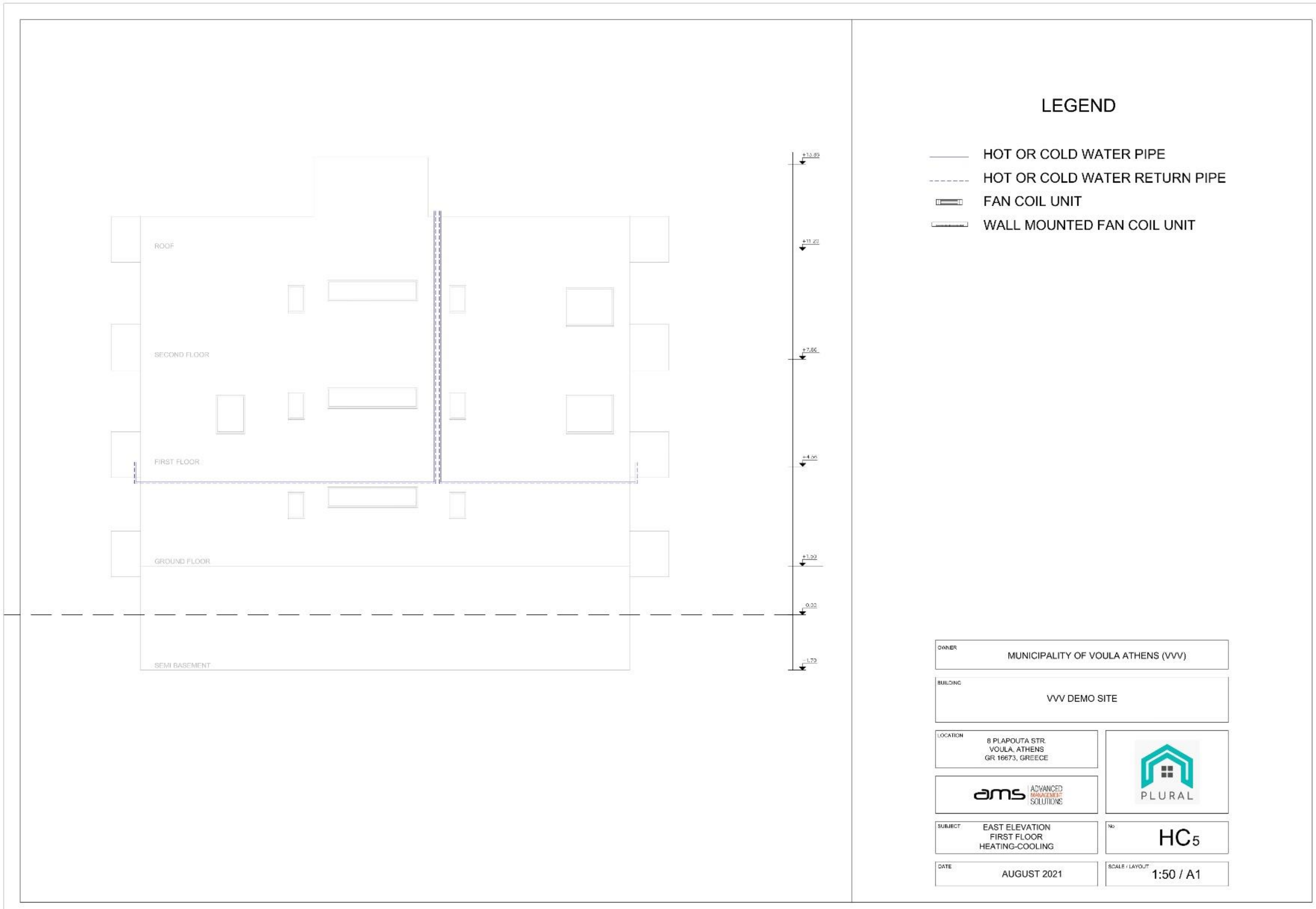
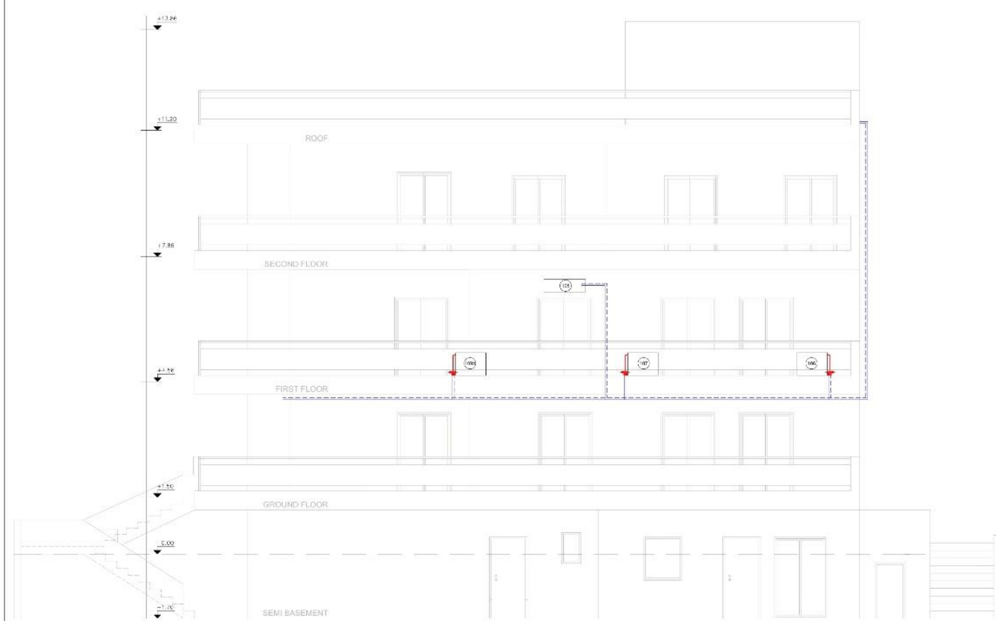

ROOF
SECOND FLOOR
FIRST FLOOR
GROUND FLOOR
SEMI BASEMENT
LEGEND
HOT OR COLD WATER PIPE
HOT OR COLD WATER RETURN PIPE
FAN COIL UNIT
WALL MOUNTED FAN COIL UNIT
OWNER
MUNICIPALITY OF VOULA ATHENS (VVV)
BUILDING
VVV DEMO SITE
LOCATION
8 PLAPOUTA STR.
VOULA, ATHENS
GR 16673, GREECE
ams ADVANCED MANAGEMENT SOLUTIONS
PLURAL
SUBJECT
EAST ELEVATION
FIRST FLOOR
HEATING-COOLING
HC5
DATE
AUGUST 2021
SCALE / LAYOUT
1:50 / A1



LEGEND

HOT OR COLD WATER PIPE
HOT OR COLD WATER RETURN PIPE
FAN COIL UNIT
WALL MOUNTED FAN COIL UNIT

OWNER: MUNICIPALITY OF VOULA ATHENS (VVV)	
BUILDING: VVV DEMO SITE	
LOCATION: 8 PLAPOUTA STR. VOULA, ATHENS GR 16673, GREECE	PLURAL
ams ADVANCED MANAGEMENT SOLUTIONS	
SUBJECT: SOUTH ELEVATION FIRST FLOOR HEATING-COOLING	No: HC6
DATE: AUGUST 2021	SCALE / LAYOUT: 1:50 / A1

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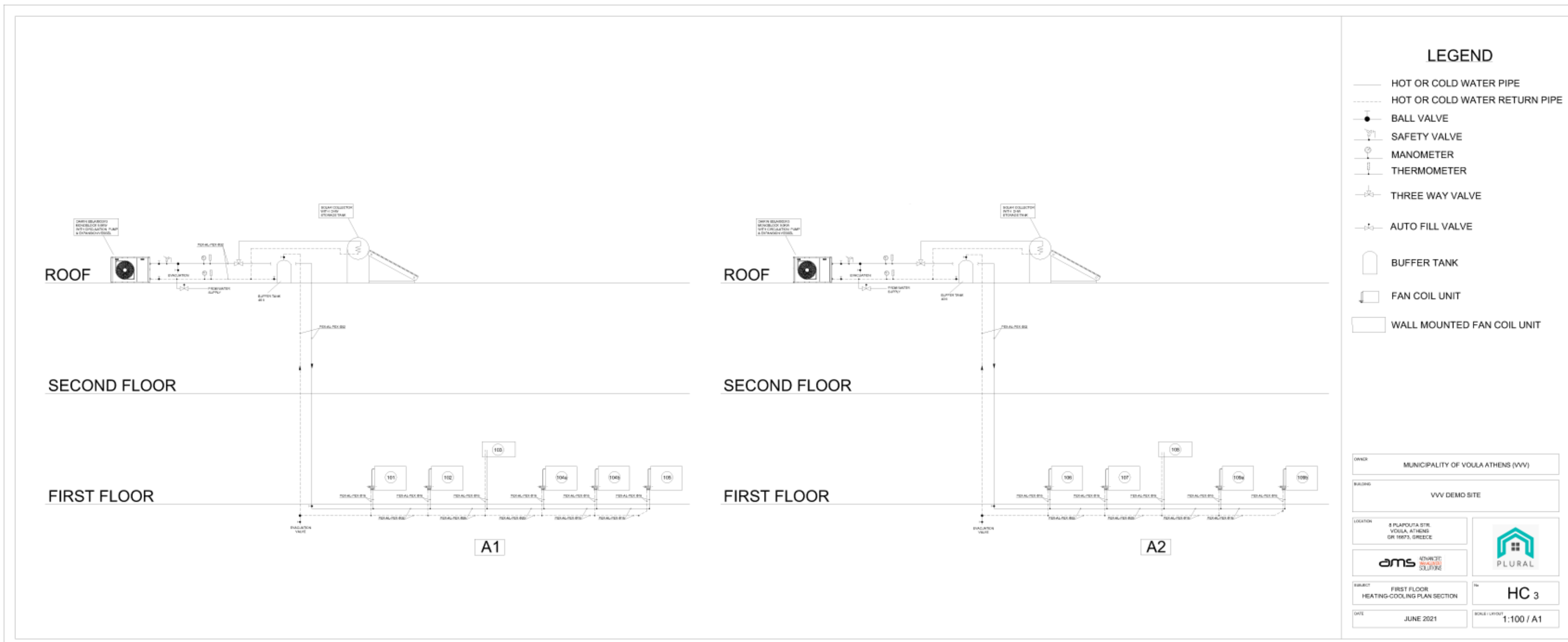

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LEGEND
COLD WATER PIPE
HOT WATER PIPE
NON RETURN VALVE
BALL VALVE
HOT & COLD WATER TAPS
WATER HEATER
WATER CONSUMPTION METER
OFFICE ROOM
BATHROOM
STAIRCASE
BEDROOM 2
BEDROOM 1
HALL
KITCHEN
BEDROOM
ENTRANCE APARTMENT 1
ENTRANCE APARTMENT 2
A1
A2
LIVING ROOM
DINING ROOM
OWNER
MUNICIPALITY OF VOULA ATHENS (VVV)
BUILDING
VVV DEMO SITE
LOCATION
8 PLAPOUTA STR.
VOULA, ATHENS
GR 16673, GREECE
ams ADVANCED MANAGEMENT SOLUTIONS
PLURAL
SUBJECT
PLURAL RENOVATION STATE
FIRST FLOOR PLAN
HOT & COLD WATER SUPPLY
No
EM 1
DATE
DECEMBER 2021
SCALE / LAYOUT
1:50 / A1


SOLAR PANELS
ROOF
SECOND FLOOR
TO BATHROOM'S LOFT (A2 APARTMENT)
TO BATHROOM'S LOFT (A1 APARTMENT)
FIRST FLOOR
GROUND FLOOR
SEMI BASEMENT
LEGEND
HOT WATER PIPE
RETURN WATER PIPE
TRADITIONAL ETICS INSTALLATION BY MUNICIPALITY OF VVV
OWNER
MUNICIPALITY OF VOULA ATHENS (VVV)
BUILDING
VVV DEMO SITE
LOCATION
8 PLAPOUTA STR.
VOULA, ATHENS
GR 16673, GREECE
SUBJECT
PLURAL RENOVATION STATE
EAST ELEVATION
FIRST FLOOR - DHW
EM2
DATE
DECEMBER 2021
1:50 / A1

4.2 Czech demonstration building – Kasava

Compared to the status of the PLURAL deliverable D2.2 (submission date 3.1.22), several changes of the heating system design were done in the meanwhile. An important change was the decision to use one instead of two heat pumps and to realize one single heating system for the whole building instead of one per apartment.

The actualized design of the heating system is shown in this chapter. Further, important components and boundary conditions are discussed which are needed to meet the requirements of the developed heating system. For components that are not mentioned in the following, standard products can be suggested by the heating company that will install the heating system.

As the final design of the façade modules and the choice of the pipes for the eWHC are still pending, the size of the heating loops might slightly change in the future.

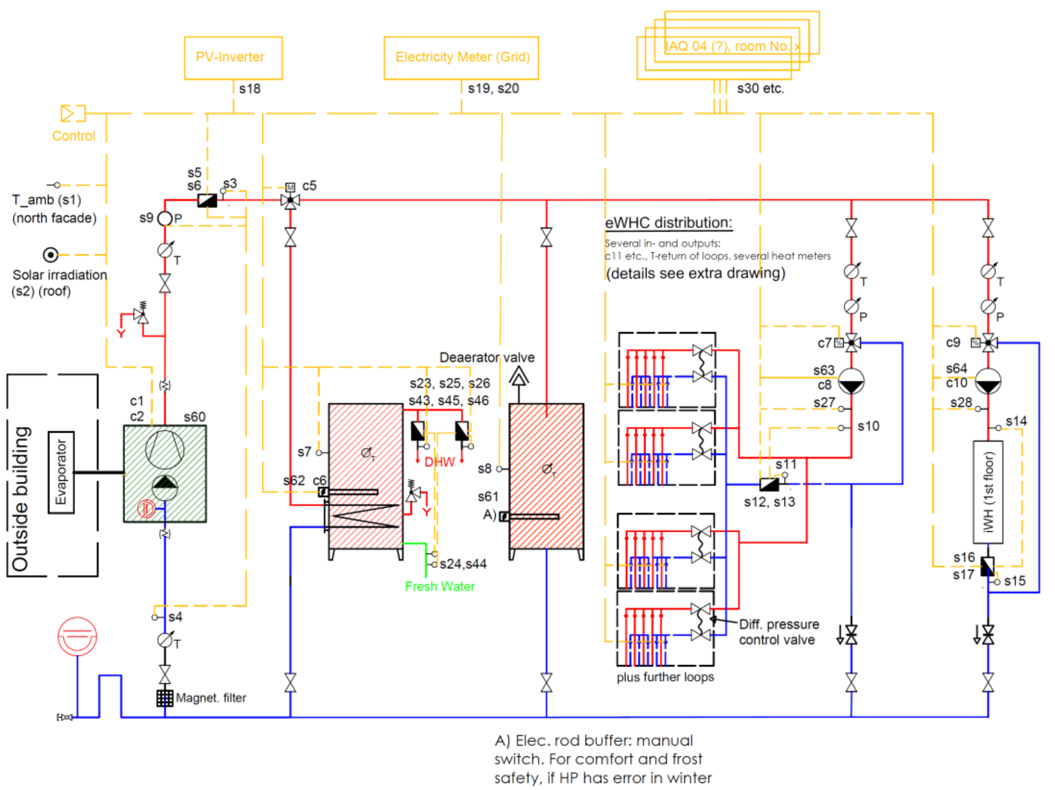

FIGURE 4.2: ACTUALIZED VERSION OF THE SCHEME OF THE HEATING SYSTEM OF KASAVA DEMO INCLUDING THE CONTROL (TOOLBOX) PART IN YELLOW

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In the heating system (Figure 4.2) the heat pump is the main heat generating component. To achieve safety against legionella in the DHW, an electric heating rod is installed in the DHW storage which can be switched on by the system control. A second heating rod is installed in the space heating buffer storage. This second rod can only be switched on manually and is a backup device in case of malfunctioning of the heating system.

The DHW is provided by a single storge tank and metered per apartment. The space heating is distributed via the external wall heating system and, for the newly constructed walls of the 1st floor that are not a part of the PLURAL project, via internal wall heating system.

4.2.1 Space heating distribution

The following figures show floor plans of the house in Kasava with the interior piping from the storage tanks until the circuit manifolds for space heating of eWHC and internal wall heating (and the DHW piping). Furthermore, the position of the manifold and the amount of heating loops can be seen. More details like the length of the pipes can be found in the Annex 6.2.

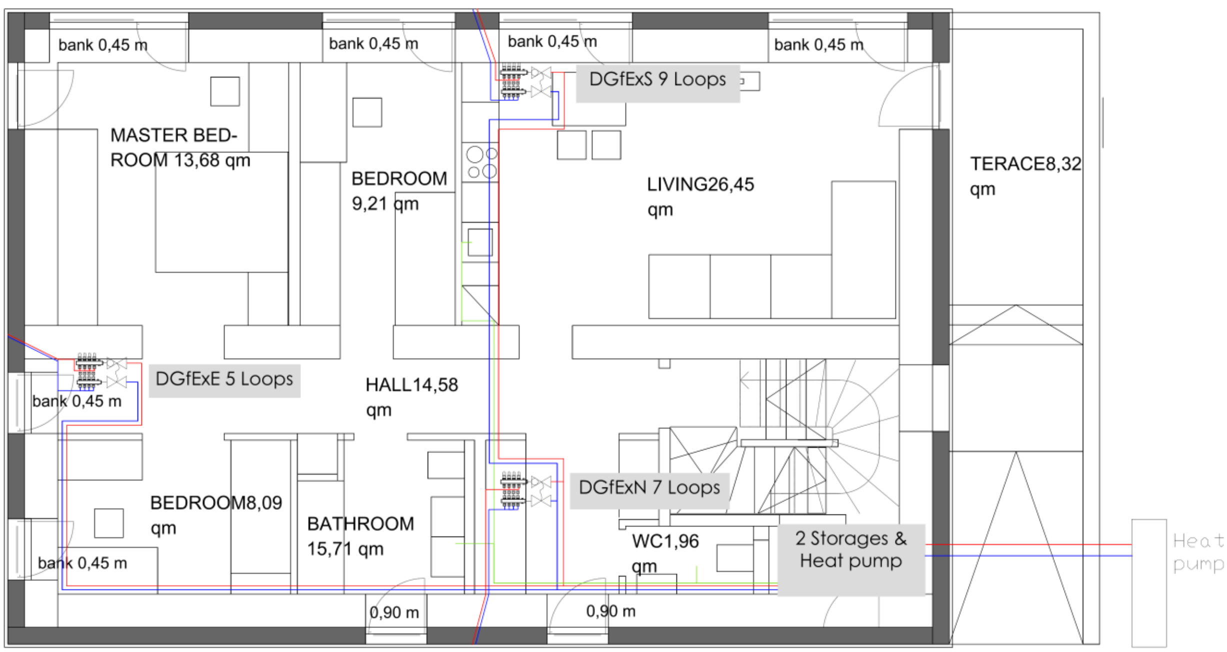

FIGURE 4.3: PIPING AND DISTRIBUTORS (DGF_) FOR THE HEAT DISTRIBUTION OF THE GROUND FLOOR

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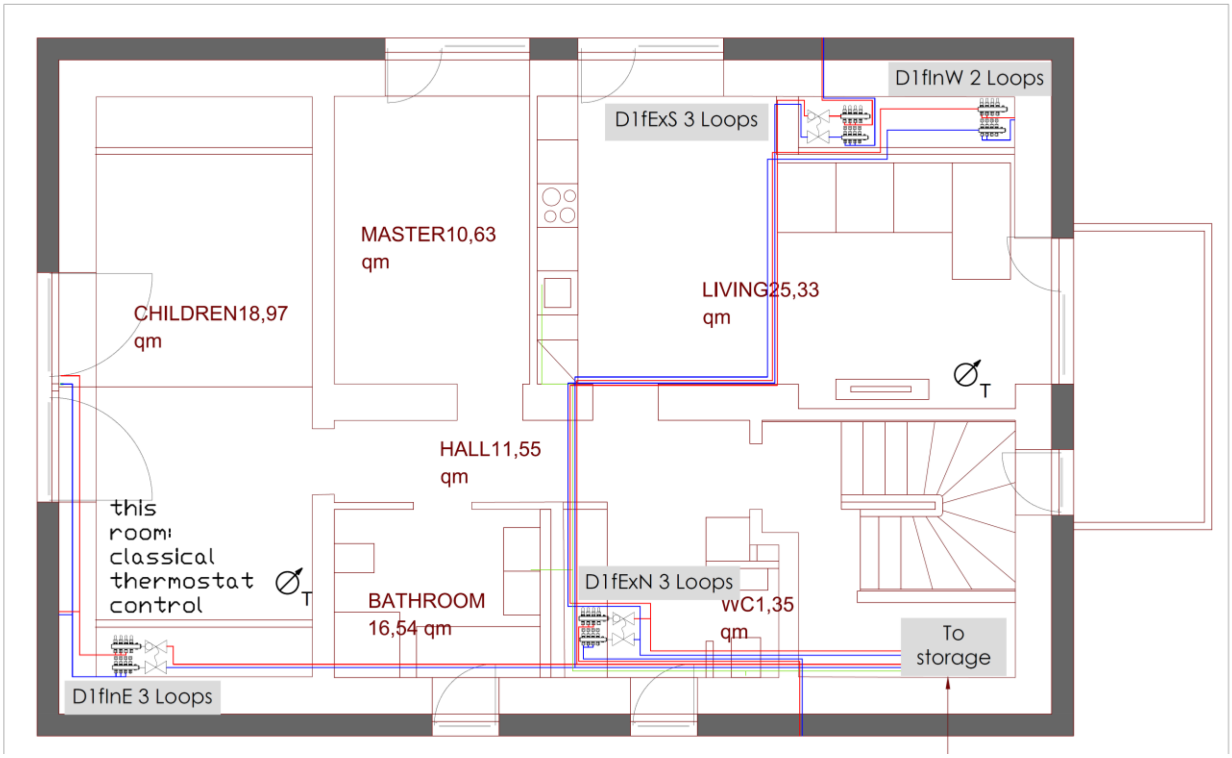

FIGURE 4.4: PIPING AND DISTRIBUTORS (D1F...) FOR THE HEAT DISTRIBUTION OF THE FIRST FLOOR

At the distributors, the pipes of the heating loops are connected and lead through ducts in the old façade towards outside, where these pipes can be connected to the heating meanders (Figure 4.5) that are pre-mounted in the facade modules.

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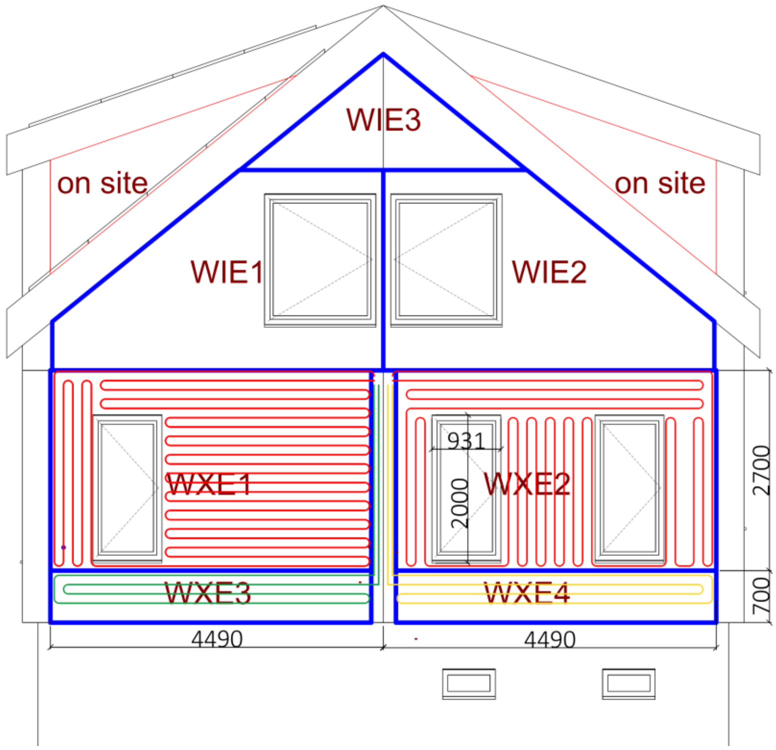

FIGURE 4.5: EAST FAÇADE OF THE KASAVA DEMO AS EXAMPLE WITH GRID OF THE FAÇADE MODULES (BLUE BORDERS) AND HEATING LOOP MEANDERS (OTHER COLORS). THE FINAL DESIGN OF THE FAÇADE MODULES IS STILL PENDING AND MINOR CHANGES IN THE LOOP DESIGN ARE EXPECTED

Figure 4.6 shows a generic scheme of the distributors for the eHWC. Each pair of distributors is passively controlled by a differential pressure control valve that keeps the pressure in the loops of its distributors constant, regardless of how many of the loops are open or closed at the moment. The flow distributor (with red colour) has manual flow meters that allow for regulating the mass flow in each loop individually. The return distributor has electrical actuators that allow the system control to open and close loops individually depending on the room temperature set-point of the room the loop is dedicated to. Further, the return temperature of each loop is measured with temperature sensors at the distributors.

An example product of a pair of distributors inside a cabinet with differential pressure control valve, flow meters, and electric actuators is shown in Figure 4.7. Missing in the figure are the temperature sensors at the return pipes of the loops.

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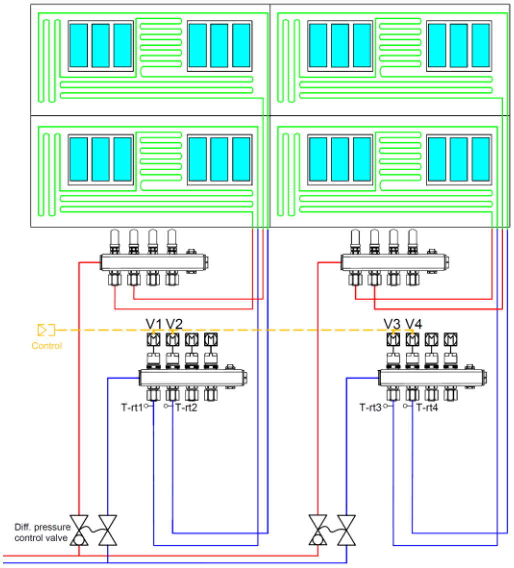

FIGURE 4.6: ACTUALIZED VERSION OF THE SCHEME OF THE HEAT DISTRIBUTION. THE HEATING LOOPS OF THE EWHC ARE CONNECTED TO THE HEATING SUPPLY VIA DISTRIBUTORS. THE VALVES AT THE DISTRIBUTORS ARE CONTROLLED BY THE SYSTEM CONTROLLER (TOOLBOX)

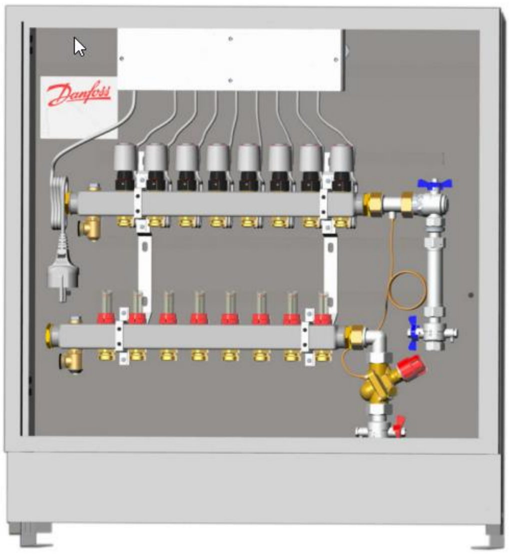

FIGURE 4.7: EXAMPLE OF A DISTRIBUTOR (MANIFOLDS) INSIDE A CABINET. HERE WITH FIVE POSSIBLE JUNCTIONS FOR HEATING LOOPS. IN THE RETURN (PIPES WITH BLUE ELEMENTS): ELECTRICAL ACTUATORS THAT CAN CLOSE EACH LOOP. IN THE FLOW (RED): SIGHT GLASSES WITH VALVES TO ADJUST THE MASS FLOW IN EACH LOOP (SOURCE: DANFOSS)

For the building, seven distributor pairs are needed. Table 4.8 shows for each distributor pair the number of loops that will be connected and the sum of the flow rates of the loops. For the mass flow rate of each loop, see Annex 6.2.

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TABLE 4.8: DISTRIBUTORS OF THE SPACE HEATING DISTRIBUTION WITH NUMBER OF HEATING LOOPS AND TOTAL FLOW RATE PER DISTRIBUTOR.

Distributor	Heating unit	Number of loops connected	Flow rate (kg/h)
DGfExE	eWHC	5	220
DGfExS	eWHC	9	410
DGfExN	eWHC	7	260
D1fExN	eWHC	3	125
D1fExS	eWHC	3	115
D1fInW	Internal wall heating	2	70
D1fInE	Internal wall heating	3	85
Total	-	*32*	*1'280*

4.2.2 Domestic hot water

The standard stainless steel DHW storage tank EKHWS(U)-D of Daikin will be used in the building (**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**). The DHW supply of both apartments will be connected to the tank. Energy and temperature of each of the connections will be measured with a heat meter.

The DHW tank has the following specifications:

- Height: 1745 mm
- Diameter: 595 mma
- Efficiency Class B (1.6 kWh/24h)
- Heat exchanger: stainless steel coil, 1.8 m^2 surface
- Integrated electric booster heater: 3 kW

The electric booster heater can be used for start-up after installation, to heat the storage to higher temperatures for legionella safety, and to keep the DHW-comfort in case of malfunctioning of the HP.

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FIGURE 4.8: DHW STORAGE TANK EKHWS(U)-D OF DAIKIN (SOURCE: DAIKIN[7])

4.3 Spanish virtual demonstration building – Terrassa

As described several times in the current report, the demonstration building renovation in Terrassa will not include any heating or cooling systems. Therefore, no drawings and simulations were made for this case.

[7] https://www.daikin.gr/el_gr/products/ekhws-d3v3.html

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5 Conclusions

WP2 deals with the identification of suitable technologies and materials for the PLURAL PnU kits to be formed in order to fulfill the goals of the project. Task 2.4 in particular focuses on the selection of the most suitable heating and cooling technologies to be matched with the proposed PnU renovation solutions in the three demonstration buildings.

To justify the selection of the appropriate heating and cooling systems a basic review of most of the available conventional and more innovative technologies was carried out in order to underline their basic advantages and drawbacks. The previous findings were then compared with the special characteristics of the PnU kits and the renovation scheme that is planned to be followed at each demonstration building. The nature of PnUs themselves and the integrated systems that has been either their core concept (piping system for eWHC) or the best available solution (fan coil for the SmartWall) led to the basic technology type selection. This was the air to water heat pump which is also going to be used for the virtual demonstration buildings. An alternative of a ground source heat pump might be a better choice where realistic for the virtual ones.

It should be mentioned that the eAHC PnU kit will utilize by definition an innovative ventilation unit with active heat recovery ability and the Terrassa renovation scheme does not include any further heating or cooling systems. This fact leaves no space for selecting any other system as it is already decided that heating and cooling will be served by the main existing systems of the building and the ventilation unit will contribute within its potential.

In order to further design the heating and cooling systems for the Greek case and just the heating system for Czech case the respective profiles and demands were calculated per living space of the buildings using different but suitable for each case methods and software. Demands were also calculated for the Spanish demo.

The same analysis was not possible to be carried out for the virtual demonstration buildings as there are still not full data for this. The effort is all gathered to the real demonstrators that are more demanding in terms of choosing the equipment that has to be ordered or prepared on time. Heating and cooling demands (where applicable) and sizing of the system will be included and carried out in Task 7.5 – "PLURAL systems installation at virtual demo buildings – Energy performance modelling for all demo cases".

Next step was to choose the appropriate heat pump type and model. For the Voula demonstration building a DAIKIN monobloc heat pump was chosen due to space limitations. One unit per apartment will be installed which will provide both heating and cooling and DHW preparation. For the Kasava case

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one heat pump for both apartments of the building was chosen. It is a split type heat pump and will provide heating and DHW preparation.

The final part of the current deliverable is to design the overall system and specify all the auxiliary components that are needed for its operation. Simulation were also performed in order to validate the selection of the systems. For the Greek demonstration building every component is defined along with its relevant quantities while the same stands for the Czech case. Drawings of the full systems were also made. All the necessary equipment lists will be formed in order to be ordered as soon as possible. Based on the availability and cost slight changes might occur.

The main purpose of Task 2.4 was achieved and the heating and cooling technology was selected and the respective systems of the demonstration buildings in Voula and in Terrassa were sized, designed and simulated. The outcome is reported in D2.4.

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6 ANNEXES

6.1 Assumptions for heating and cooling load calculations of the Greek demonstration building

6.1.1 Heating loads calculation assumptions

According to DIN 4701/77, space related thermal losses are considered via:

a) Heat permeability losses Q_0, caused by the surrounding structural elements (walls, openings, floors, ceilings, etc.).
b) Losses due to augmentations
c) Losses due to space ventilation Q_L.

A) Losses caused by heat permeability are calculated via the formula:

Where:

Q_o: Heat losses (W or Kcal/h)

F: Surface area of structural element (m^2)

k: Heat transfer coefficient – U value (W/m^{2}K or Kcal/m^{2}h)

t_i: Room temperature (^{o}C)

t_a: Outdoor air temperature (^{o}C)

B) The augmentations are calculated in % and divided into:

B_1) Z_H increase (augmentation) for the orientation effect:

Z_H= -5 for S, SW, SE

Z_H= +5 for N, NW, NE

Z_H= 0 for W and E

B_2) increase occurred in Z_U + Z_A=Z_D due to downtime and cold external walls effect. Z_D increase is determined based on D=Q_o/ (F_{ges} Δt).

Where:

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F_{ges} is the total surface area surrounding the space

Operating hours of the heating system:

Z_D for DIN77			
	Value D		
Operation type	0.1-0.29	0.30-0.69	0.70-1.49
0 downtime hours	7	7	7
8-12 downtime hours	20	15	15
12-16 downtime hours	30	25	20

Therefore, the heating demands accompanied by the aforementioned increases are:

(W or Kcal/h)

C) Ventilation losses (Q_L) are alternatively calculated:

C_1) From the equation which calculates the required ventilation:

(W or Kcal/h)

Where:

V: volume of the incoming air (m^3/s)

C: Specific heat capacity of air (Kj/g K)

ρ: Air density (kg/m^3)

C_2) According to the calculation ratio for crack related losses (in case no ventilation exists):

$Q_L = \Sigma Q A_i$

, for every opening.

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The corresponding parameters regarding the above equation are:

α: Air penetration coefficient

Σl: total perimeter of the opening (m)

R: Penetration coefficient

H: Position and windfall coefficient

Δt: Temperature difference (°C)

Z_r: Ratio associated with corner windows (in case of corner windows the value equals to 1.2 instead of 1 which indicated the non-corner windows)

D) The final total of heat losses is the sum of Q_T and Q_L:

(W or Kcal/h)

The results are presented tabulated as follows:

a. At the top of the table, the structural elements losses due to thermal permeability are demonstrated. The table columns represent the following indexes:

- Structural Element Type (e.g. W=Wall, O=Opening, C=ceiling, F=Floor)
- Orientation
- Thickness
- Length
- Height or Width
- Surface
- Number of similar surfaces
- Total surface area
- Subtracted surface
- Final Calculated area
- Heat Transfer Coefficient k or U
- Temperature Difference Δt
- Net heat losses

b. At the bottom of the table the increases described above, and the losses of ventilation are added, in full analysis.

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6.1.2 *Cooling loads calculation assumptions*

1. *External Walls:*

Where:

- Q_i: Load during hour i
- i: Hours of the day
- K: Thermal transmittance of wall (the U-value)
- A: Surface area of wall
- Dt_{ei}: The equivalent temperature difference for hour i

The equivalent temperature difference is obtained while considering the indexes of wall weight and orientation. A correction factor is used to rectify the values (the calculation is conducted via the daily fluctuation and considering the temperature difference (indoor – outdoor) of the calculated month at 3 pm) and wall color.

For darker colour:

- $Dt_{e\,i} = (Dt_{em\,i} + D)$

For middle dark color:

- $Dt_{e\,i} = 0.78 \times (Dt_{em\,i} + D) + 0.22 \times (Dt_{es\,i} + D)$

For light color:

- $Dt_{ei} = 0.55 \times (Dt_{em\,i} + D) + 0.45 \times (Dt_{es\,i} + D)$

Where:

- D: Coefficient of wall correction
- $Dt_{em\,i}$: Equivalent temperature difference depending on wall orientation and weight, for wall exposed to sunlight
- $Dt_{es\,i}$: Equivalent temperature difference from table, depending on weight, for shaded wall (north orientation)

In case the wall is shaded, then this part of wall is calculated via the equivalent temperature difference (Dtes i +D), while the rest of it via the equivalent temperature difference:

$$Q_i = (K \times Dt_{e\,i} \times R_e) + (K \times (Dt_{es\,i} + D) \times R_{es})$$

Where:

- R_e: Surface exposed to sunlight
- R_{es}: Shaded surface

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2. Roofs:

Calculation of loads linked to roofs is similar to the calculation type exploited for external walls, by using different table of equivalent temperatures differences.

3. Internal walls:

Calculation of loads regarding internal walls results from multiplying the thermal transmittance of the wall times its corresponding surface area and the equivalent temperature difference for every hour:

$$Q_i = K \times A \times Dt_i$$

Where:

- Q_i: Load during hour i
- i: Hours of the day
- K: Thermal transmittance of wall (the U-value)
- A: Surface area of wall
- Dt_{ei}: The equivalent temperature difference of non-conditioned spaces for hour i

4. Floors:

Floors related loads are calculated from the following type:

$$Q = K \times A \times Dt$$

Where:

- Q: Calculated load
- K: Thermal transmittance of floor (U-value)
- A: Surface area of floor
- Dt: The equivalent temperature difference of the cooled space relative to floor (considered stable)

5. Openings:

The loads corresponding to the openings, result from the sum of thermal conductivity loads plus the radiation loads.

$$Q_i = Q_{ki} + Q_{ai}$$

Where:

- Q_i: Total load from the openings during hour i
- Q_{ki}: Thermal conductivity load during hour i
- Q_{ai}: Radiation load during the hour i

The load corresponding to the thermal conductivity (Q_{ki}) is given by the following:

$$Q_{ki} = K \times A \times D_{ti}$$

Where:

- i: Hours of the day
- K: Thermal transmittance of the opening (U-value)
- A: Surface area of the opening
- D_{ti}: The equivalent temperature difference for openings' conductivity during hour i

Load value due to radiation, results from multiplying the surface area of the opening, times the solar thermal gain, through common glass which has been corrected via the necessary coefficients:

$$Q_{ai} = (A \times D_i \times ES_{out\ i} \times E_{Sin} \times S\ 1 \times S\ 2 \times (1 + (A_t \times 0.007 / 300))$$

$$\times (1 + ((19.5\text{-}T_{adp}) \times 0.005 / 4))) + (A \times D_{es\ i} \times (1 - ES_{out\ i}) \times E_{Sin} \times S\ 1 \times S\ 2 \times$$

$$(1 + (A_t \times 0.007 / 300)) \times (1 + ((19.5\text{-}T_{adp}) \times 0.005 / 4)))$$

Where:

- i: Hours of the day
- A: Surface area of the opening
- D_i: Solar thermal gain from the common glass, for the selected orientation
- D_{esi}: Solar thermal gain from the common shaded glass (north orientation)
- E_{Souti}: Coefficient of external shading
- E_{Sin}: Overall coefficient of solar thermal gain through
- S1: This coefficient depends from the opening frame. Its value equals to 1 for windows with wooden frame and to 1.17 for windows without frame or with metallic frame.
- S2: Coefficient associated with the occurrence or non-occurrence of fog. Its value equals to 1 for area without fog and 0.90 for areas with fog.
- A1: Altitude of the constructed building
- T_{adp}: Dew point value

6. Light Loads:

Light loads are calculated via the following relationship:

$$Q_{fi} = (F_{1i} \times 1.25 \times c) + (F_{2i} \times c)$$

Where:

- Q_{fi} : Light load during hour i

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- F_{1i} : Power of fluorescent lamps during hour i
- F_{2i} : Power of incandescent lamps during hour i
- c : Fixed unit conversion (0.86 for Kcal/h, 3.4 for Btu/h and 1 for Watt)

7. Calculation of occupants' loads:

Thermal load from occupants is divided into sensible and latent (sensible and latent heat load). Relations are calculated from the following:

$$Q_{ai} = \sum_{j=1}^{k} Fa_j \times N_{ji}$$

$$Q_{li} = \sum_{j=1}^{k} Fl_j \times N_{ji}$$

Where:

- Q_{ai} : Sensible load from persons during hour i
- Q_{li} : Latent load from persons during hour i
- j : Individuals' degree of activity according to the Carrier table.
- Fa_j : The sensible load of a person under "j" activity degree, which depends on the dry bulb temperature of the room.
- Flj : The latent load of a person under "j" activity degree. It depends on room's dry bulb temperature.
- Nji : The number of persons under "j" activity degree that occupy the space during hour i

More specifically, depending on the activity degree of the occupants and the internal temperature of the conditioned space, the latent and sensible loads are obtained from the following table:

Table 6.1: Sensible & Latent Occupants' Loads Depending on Their Activity Degree

Persons' s degree of activity	Sensible and Latent loads (in Kcal/h) according to the interior space temperature									
	T=23.5 °C		T=24.5 °C		T=25.5 °C		T=26.5 °C		T=27.5 °C	
	S	L	S	L	S	L	S	L	S	L
Sitting, in immobility	60	26	56	30	52	34	48	38	44	52

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Sitting, in light work	64	39	59	44	55	48	50	53	46	57
Sitting and eating	76	69	70	75	65	80	60	85	55	90
Office work	76	54	70	60	65	65	60	70	55	75
Standing and slow walking	90	70	83	77	77	83	71	89	65	95
Sitting work (Factory)	100	98	93	105	86	112	79	119	73	125
Light work (Factory)	100	160	93	167	86	174	79	181	73	187
Moderate Dance	120	202	111	211	103	219	95	227	87	235
Heavy work (Factory)	165	240	153	252	142	263	131	274	121	284
Heavy work (Gym)	187	263	173	277	160	290	147	303	135	315

8. *Devices' Loads:*

Similar to the occupants' loads, the devices' loads are divided into sensible and latent heat load. The calculation equations are presented below:

$$Q_a = \left(\sum_{j=1}^{k} Fa_j \times N_j\right) + Q_1$$

$$Q_l = \left(\sum_{j=1}^{k} Fl_j \times N_j\right) + Q_2$$

Where:

- Q_a : The overall sensible load from the devices
- Q_l : The overall latent load from the devices
- j : Device type according to the following table by Carrier
- Fa_j : The sensible load of a device type j
- Fl_j : The latent load of a device type j
- N_j : The number of j type devices functioning inside the space

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- Q_1 : Overall sensible load from devices not included in the tables
- Q_2 : Overall latent load from devices not included in the tables

Specifically, the thermal gains of the various devices (in kcal/h), are obtained from the following table:

Type of device	Sensible load (kcal/h)	Latent load (kcal/h)
Gas based (small)	500	125
Gas based (big)	1500	400
Electric 300 W	400	200
Electric 1 KW	600	150
Electric 2 KW	1200	300
Electric 4 KW	2000	800

9. Loads from cracks:

These loads are considered only when there are no air changes due to cooling devices and are calculated from the following type:

$$Q_i = \left(\sum_{j=1}^{n} P_j \ x \ a_j \ x \ b\right) x \ Dt_i$$

Where:

- Q_i : The overall load from cracks during hour i
- P_j : The perimeter of opening j
- n : Number of openings
- a_j : The air penetration coefficient for the opening j. It depends on the type of opening.
- b : Coefficient depending on the building’s exposure to winds, the relation of surface area of the exterior openings to the surface area of the interior openings and the openings’ position. Its value varies from 0.24 to 1.6.
- Dt_i : The difference between the external and the internal dry bulb temperature during hour i.

10. Ventilation:

This calculation concerns the introduction of ambient air for ventilation of the cooling spaces. The ventilation load is divided to sensible and latent, and is calculated via the following equations:

$$Qa_i = 0.29 \ x \ V \ x \ n \ x \ Dt_i$$

$$Ql_i = 0.71 \ x \ V \ x \ n \ x \ D_g$$

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Where:

- Qa_i : The sensible ventilation load during hour i.
- Ql_i : The latent ventilation load during hour i.
- V : The volume of space.
- n : The number of air changes per hour.
- Dt_i : Difference between external and internal dry bulb temperature per hour i.
- D_g : Difference of exterior and interior absolute humidity. This difference is considered constant for all calculation hours.

Calculation results are presented aggregated and detailed for every hour and are demonstrated in tables based on the following groups:

a. Table of structural components, columns of the table are:

- Component type (e.g. W=Wall etc.)
- Orientation
- Heat transfer coefficient k
- Length (m)
- Height or Width (m)
- Surface area (m^2)
- Number of similar surfaces
- Total surface area (m^2)
- Subtracted surface area (m^2)
- Calculated area (m^2)
- Interior shading
- Canopy shading
- Arbitrary shading rates

b. Loads of the above table per surface and hour (Btu/h, W, or kcal/h)
c. Additional Loads per hour (Btu/h, W, or Kcal/h):

- Lighting's
- Occupants'
- Devices'

d. Overall Space Loads per hour (Kbtu/h, KW, or Kcal/h).
e. Ventilation Loads per hour (and max) (Kbtu/h, KW, or Kcal/h).

- The first group contains the geometric dimensions of the elements, as well as indications related to potential shadings on them.
- The second group presents the cooling loads as calculated for every element, according to the above calculation rules.

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- Third group consists of the loads related to the additional causes already described, namely lighting, persons, devices and cracks, and they are detailed to sensible, latent and overall load.
- The latter group presents the overall loads per hour, separately the sensible and the latent ones. Ventilation related loads are included too.

6.1.3 Detailed Heating & Cooling loads per space of Greek demonstration building

HEATING LOADS

Floor: Level 1 Room: 1
Name of room HALL-A1

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m²)	Number of surfaces	Subtracted surface area (m²)	Subtracted surface area (m²)	Surface area calculated (m²)	Coef. k (W/m²K)	Temp/ture difference (°C)	Net losses (W)
I1	internal			1.2	3.3	3.96	1	3.96	2.10	1.86	1.8	10.00	33.48
O17	internal	α		1	2.1	2.10	1	2.10		2.10	3.48	10.00	73.08
F1	internal			1.3	3.78	4.91	1	4.91		4.91	2	10.00	98.20

Thermal Losses Qo		205
Total Increase $Z_D + Z_H$=	20%	41
Increase due to orientation ZH=	0	
Increase due to downtimes ZD=	20	
D=Qo/(Fges x Δt) = 205/ (58.5 χ 17) = 0.21		
TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH)		246
CRACK related LOSSES QL = ΣQAi (QAi = axΣIxRxHxΔtxZΓ)=		
Building characterizing num. H=	0.6	
Room characterizing num. R (or r)=	0.9	
Corner windows coef. ZΓ=	1	
LOSSES from AIR CHANGES QL = VxρxcxΔt =		86.09
Volume of space V = 2.6x3.5x3.3=	30	
Number of air changes per hour n =	0.5	
TOTAL of THERMAL LOSSES Q_{tot} = QT + QL		332

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Floor: Level 1 Room: 2

Name of room LIVING & DINING ROOM – A1

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m²)	Number of surfaces	Subtracted surface area (m²)	Subtracted surface area (m²)	Surface area calculated (m²)	Coef. k (W/m²K)	Temp/ture difference (°C)	Net losses (W)
W1	N			5.47	3.3	18.05	1	18.05	3.21	14.84	0.4	17.00	100.9
O16	N	α		1.44	2.23	3.21	1	3.21		3.21	1.3	17.00	70.94
W1	W			4.88	3.3	16.10	1	16.10	3.21	12.89	0.4	17.00	87.65
O1	W	α		1.44	2.23	3.21	1	3.21		3.21	1.3	17.00	70.94
W2	S			1.13	3.3	3.73	1	3.73		3.73	0.5	17.00	31.70
W1	W			3.44	3.3	11.35	1	11.35	3.21	8.14	0.4	17.00	55.35
O2	W	α		1.44	2.23	3.21	1	3.21		3.21	1.3	17.00	70.94
F1	internal			3.06	4.4	13.46	1	13.46		13.46	2	10.00	269.2

Thermal Losses Qo		758
Total Increase $Z_D + Z_H$ =	25%	189
Increase due to orientation ZH=	5	
Increase due to downtimes ZD=	20	
D=Qo/(Fges x Δt)= 758/ (157.8 x 17) = 0.28		
TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH)		947
CRACK related LOSSES QL = ΣQAi (QAi = axΣIxRxHxΔtxZΓ)=		300.3
Building characterizing num. H=	0.58	
Room characterizing num. R (or r)=	0.9	

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Corner windows coef. ZΓ= 1

LOSSES from AIR CHANGES QL = VxρxcxΔt = 355.7
Volume of space V = 7.52x5x3.3= 124
Number of air changes per hour n = 0.5

TOTAL of THERMAL LOSSES Q_{tot} = QT + QL 1603

Floor: Level 1 Room: 3
Name of room KITCHEN – A1

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m²)	Number of surfaces	Subtracted surface area (m²)	Subtracted surface area (m²)	Surface area calculated (m²)	Coef. k (W/m²K)	Temp/ture difference (°C)	Net losses (W)
W2	W			1.6	3.3	5.28	1	5.28		5.28	0.5	17.00	44.88
W1	N			2.69	3.3	8.88	1	8.88	1.37	7.51	0.4	17.00	51.07
O15	N	α		1.44	0.95	1.37	1	1.37		1.37	1.3	17.00	30.28

Thermal Losses Qo 126

Total Increase $Z_D + Z_H$ = 25% 32
Increase due to orientation ZH= 5
Increase due to downtimes ZD= 20
D=Qo/(Fges x Δt)= 126/ (69.4 x 17) = 0.11

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH) 158

CRACK related LOSSES QL = ΣQAi (QAi = axΣlxRxHxΔtxZΓ)= 70.96
Building characterizing num. H= 0.58
Room characterizing num. R (or r)= 0.9

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Corner windows coef. ZΓ= 1

LOSSES from AIR CHANGES QL = VxρxcxΔt = 320.1
Volume of space V = 4.7x3.4x3.3= 37
Number of air changes per hour n = 1.5

TOTAL of THERMAL LOSSES Q_{tot} = QT + QL 549

Floor: Level 1 Room: 4
Name of room BEDROOM 1 – A1

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m²)	Number of surfaces	Subtracted surface area (m²)	Subtracted surface area (m²)	Surface area calculated (m²)	Coef. k (W/m²K)	Temperature difference (°C)	Net losses (W)
W1	N			3.84	3.3	12.67	1	12.67	3.21	9.46	0.4	17.00	64.33
O14	N	α		1.44	2.23	3.21	1	3.21		3.21	1.3	17.00	70.94

Thermal Losses Qo 135

Total Increase $Z_D + Z_H$ = 25% 34
Increase due to orientation ZH= 5
Increase due to downtimes ZD= 20
D=Qo/(Fges x Δt)= 135/ (74.8 x 17) = 0.11

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH) 169

CRACK related LOSSES QL = ΣQAi (QAi = axΣlxRxHxΔtxZΓ)= 118.5
Building characterizing num. H= 0.58
Room characterizing num. R (or r)= 0.9

Corner windows coef. ZΓ=	1	
LOSSES from AIR CHANGES QL = VxpxcxΔt =		126.0
Volume of space V = 3.6x3.7x3.3=	44	
Number of air changes per hour n =	0.5	
TOTAL of THERMAL LOSSES Q_{tot} = QT + QL		414

Floor: Level 1 Room: 5

Name of room OFFICE ROOM – A1

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m²)	Number of surfaces	Subtracted surface area (m²)	Subtracted surface area (m²)	Surface area calculated (m²)	Coef. k (W/m²K)	Temp/ture difference (°C)	Net losses (W)
W1	N			4.14	3.3	13.66	1	13.66	3.21	10.45	0.4	17.00	71.06
O13	N	α		1.44	2.23	3.21	1	3.21		3.21	1.3	17.00	70.94
W2	internal			4.21	3.3	13.89	1	13.89	1.74	12.15	0.5	17.00	103.3
O12	interanl	α		1.45	1.20	1.74	1	1.74		1.74	1.3	17.00	38.45

Thermal Losses Qo		284
Total Increase $Z_D + Z_H$ =	25%	71
Increase due to orientation ZH=	5	
Increase due to downtimes ZD=	20	

D=Qo/(Fges x Δt)= 284/ (80.5 x 17) = 0.21

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH)	355

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CRACK related LOSSES QL = ΣQAi (QAi = axΣIxRxHxΔtxZΓ)=		199.0
Building characterizing num. H=	0.58	
Room characterizing num. R (or r)=	0.9	
Corner windows coef. ZΓ=	1	
LOSSES from AIR CHANGES QL = VxρxcxΔt =		140.2
Volume of space V = 3.8x3.9x3.3=	49	
Number of air changes per hour n =	0.5	
TOTAL of THERMAL LOSSES Q_{tot} = QT + QL		694

Floor: Level 1 Room: 6

Name of room BATH – A1

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m²)	Number of surfaces	Subtracted surface area (m²)	Subtracted surface area (m²)	Surface area calculated (m²)	Coef. k (W/m²K)	Temp/ture difference (°C)	Net losses (W)
W2	N			2.06	3.3	6.80	1	6.80	0.42	6.38	0.5	20	63.80
O11	N	α		0.50	0.84	0.42	1	0.42		0.42	1.3	20	10.92
I1	internal			4.66	3.3	15.38	1	15.38		15.38	1.8	13	359.9

Thermal Losses Qo		435
Total Increase $Z_D + Z_H$ =	15%	65
Increase due to orientation ZH=	0	
Increase due to downtimes ZD=	15	

D=Qo/(Fges x Δt)= 435/ (42.5 x 17) = 0.60

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH)	500

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CRACK related LOSSES QL = ΣQAi (QAi = axΣIxRxHxΔtxZΓ)=		39.05
Building characterizing num. H=	0.58	
Room characterizing num. R (or r)=	0.9	
Corner windows coef. ZΓ=	1	
LOSSES from AIR CHANGES QL = VxpxcxΔt =		153.3
Volume of space V = 1.8x3x3.3=	18	
Number of air changes per hour n =	1.5	
TOTAL of THERMAL LOSSES Q_{tot} = QT + QL		692

Floor: Level 1 Room: 7

Name of room CORRIDOR – A1

Thermal Losses Qo		0
=	20%	0
Increase due to orientation ZH=	0	
Increase due to downtimes ZD=	20	

D=Qo/(Fges x Δt)= 0/ (47.6 x 17) = 0.00

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH)		0
CRACK related LOSSES QL = ΣQAi (QAi = axΣIxRxHxΔtxZΓ)=		
Building characterizing num. H=	0.6	
Room characterizing num. R (or r)=	0.9	
Corner windows coef. ZΓ=	1	
LOSSES from AIR CHANGES QL = VxpxcxΔt =		44.59
Volume of space V = 4.81x0.98x3.3=	16	
Number of air changes per hour n =	0.5	
TOTAL of THERMAL LOSSES Q_{tot} = QT + QL		45

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Floor: Level 1 Room: 8

Name of room WC – A1

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m^2)	Number of surfaces	Subtracted surface area (m^2)	Subtracted surface area (m^2)	Surface area calculated (m^2)	Coef. k (W/m^2K)	Temperature difference (°C)	Clear losses (W)
I1	internal			2.1	3.3	6.93	1	6.93		6.93	1.8	10.00	124.7

Thermal Losses Qo		125
Total Increase $Z_D + Z_H$ =	15%	19
Increase due to orientation ZH=	0	
Increase due to downtimes ZD=	15	

D=Qo/(Fges x Δt)= 125/ (24.9 x 17) = 0.30

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH)		143
CRACK related LOSSES QL = ΣQAi (QAi = axΣIxRxHxΔtxZΓ)=		
Building characterizing num. H=	0.6	
Room characterizing num. R (or r)=	0.9	
Corner windows coef. ZΓ=	1	
LOSSES from AIR CHANGES QL = VxρxcxΔt =		20.81
Volume of space V = 1.1x2x3.3=	7	
Number of air changes per hour n =	0.5	
TOTAL of THERMAL LOSSES Q_{tot} = QT + QL		164

Level 1 Room: 9

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Name of room HALL / LIVING ROOM – A2 Apartment

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m^2)	Number of surfaces	Subtracted surface area (m^2)	Subtracted surface area (m^2)	Surface area calculated (m^2)	Coef. k (W/m^2K)	Temp/ture difference (°C)	Net losses (W)
W2	W			4.38	3.3	14.45	1	14.45	3.21	11.24	0.4	17.00	76.43
O3	W	α		1.44	2.23	3.21	1	3.21		3.21	1.3	17.00	70.94
W1	S			4.73	3.3	15.61	1	15.61	3.21	12.40	0.4	17.00	84.32
O4	S	α		1.44	2.23	3.21	1	3.21		3.21	1.3	17.00	70.94
W2	W			0.76	3.3	2.51	1	2.51		2.51	0.5	17.00	21.33
W1	S			1.27	3.3	4.19	1	4.19		4.19	0.4	17.00	28.49
I1	Interior			1.57	3.3	5.18	1	5.18		5.18	1.8	10.00	93.24
I1	Interior			1.56	3.3	5.15	1	5.15	2.10	3.05	1.8	10.00	54.90
O17	Interior	α		1	2.1	2.10	1	2.10		2.10	3.48	10.00	73.08
F1	Interior			5.21	1.76	9.17	1	9.17		9.17	2	10.00	183.4

Thermal Losses Qo 757

Total Increase $Z_D + Z_H$ = 15% 114
Increase due to orientation ZH= -5
Increase due to downtimes ZD= 20

D=Qo/(Fges x Δt)= 757/ (281.8 x 17) = 0.16

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH) 871

CRACK related LOSSES QL = ΣQAi (QAi = axΣIxRxHxΔtxZΓ)= 209.4
Building characterizing num. H= 0.58

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Room characterizing num. R (or r)= 0.9
Corner windows coef. ZΓ= 1

LOSSES from AIR CHANGES QL = VxρxcxΔt = 302.7
Volume of space V = 1x32x3.3= 106
Number of air changes per hour n = 0.5

TOTAL of THERMAL LOSSES Q_{tot} = QT + QL 1383

Level 1 Room: 10
Name of room KITCHEN – A2 Apartment

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m²)	Number of surfaces	Subtracted surface area (m²)	Subtracted surface area (m²)	Surface area calculated (m²)	Coef. k (W/m²K)	Temp/ture difference (°C)	Net losses (W)
W1	S			2.78	3.3	9.17	1	9.17	3.21	5.96	0.4	17.00	40.53
O5	S	α		1.44	2.23	3.21	1	3.21		3.21	1.3	17.00	70.94

Thermal Losses Qo 111

Total Increase $Z_D + Z_H$ = 15% 17
Increase due to orientation ZH= -5
Increase due to downtimes ZD= 20

D=Qo/(Fges x Δt)= 111/ (53.6 x 17) = 0.12

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH) 128

CRACK related LOSSES QL = ΣQAi (QAi = axΣlxRxHxΔtxZΓ)= 118.5
Building characterizing num. H= 0.58

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Room characterizing num. R (or r)=	0.9	
Corner windows coef. ZΓ=	1	
LOSSES from AIR CHANGES QL = VxρxcxΔt =		227.1
Volume of space V = 3.2x2.5x3.3=	26	
Number of air changes per hour n =	1.5	
TOTAL of THERMAL LOSSES Q_{tot} = QT + QL		474

Level 1 Room: 11

Name of room BATH – A2 Apartment

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m²)	Number of surfaces	Subtracted surface area (m²)	Subtracted surface area (m²)	Surface area calculated (m²)	Coef. k (Watt/m² K)	Temperature difference (°C)	Net losses (Watt)
W2	E			1.77	3.3	5.84	1	5.84	0.50	5.34	0.5	20	53.40
O9	E	α		0.6	0.84	0.50	1	0.50		0.50	1.3	20	13.00
I1	interior			2.43	3.3	8.02	1	8.02		8.02	1.8	13	187.7

Thermal Losses Qo		254
Total Increase $Z_D + Z_H$ =	15%	38
Increase due to orientation ZH=	0	
Increase due to downtimes ZD=	15	

D=Qo/(Fges x Δt)= 254/ (31.1 x 17) = 0.48

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH)	292
CRACK related LOSSES QL = ΣQAi (QAi = axΣIxRxHxΔtxZΓ)=	41.96

Building characterizing num. H= 0.58
Room characterizing num. R (or r)= 0.9
Corner windows coef. ZΓ= 1

LOSSES from AIR CHANGES QL = VxρxcxΔt = 95.36
Volume of space V = 1.6x2.1x3.3= 11
Number of air changes per hour n = 1.5

TOTAL of THERMAL LOSSES Q_{tot} = QT + QL 430

Level 1 Room: 12
Name of room CORRIDOR – A2 Apartment

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m²)	Number of surfaces	Subtracted surface area (m²)	Subtracted surface area (m²)	Surface area calculated (m²)	Coef. k (W/m²K)	Temp/ture difference (°C)	Net losses (W)
I1	interior			2.86	3.3	9.44	1	9.44		9.44	1.8	10.00	169.9

Thermal Losses Qo 170

Total Increase $Z_D + Z_H$ = 20% 34
Increase due to orientation ZH= 0
Increase due to downtimes ZD= 20

D=Qo/(Fges x Δt)= 254/ (31.1 x 17) = 0.48

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH) 204

CRACK related LOSSES QL = ΣQAi (QAi = axΣlxRxHxΔtxZΓ)= 41.96
Building characterizing num. H= 0.6

Room characterizing num. R (or r)=	0.9	
Corner windows coef. ZΓ=	1	
LOSSES from AIR CHANGES QL = VxρxcxΔt =		44.04
Volume of space V = 1.6x2.1x3.3=	15	
Number of air changes per hour n =	0.5	
TOTAL of THERMAL LOSSES Q_{tot} = QT + QL		248

Level 1 Room: 13

Name of room WC – A2 Apartment

Thermal Losses Qo		0
Total Increase $Z_D + Z_H$ =	20%	0
Increase due to orientation ZH=	0	
Increase due to downtimes ZD=	20	

D=Qo/(Fges x Δt)= 0/ (20.5 x 17) = 0.00

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH)		0
CRACK related LOSSES QL = ΣQAi (QAi = axΣIxRxHxΔtxZΓ)=		
Building characterizing num. H=	0.6	
Room characterizing num. R (or r)=	0.9	
Corner windows coef. ZΓ=	1	
LOSSES from AIR CHANGES QL = VxρxcxΔt =		15.89
Volume of space V = 1.2x1.4x3.3=	6	
Number of air changes per hour n =	0.5	
TOTAL of THERMAL LOSSES Q_{tot} = QT + QL		16

Level 1 Room: 14

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Name of room BEDROOM 1 – A2 Apartment

Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m²)	Number of surfaces	Subtracted surface area (m²)	Subtracted surface area (m²)	Surface area calculated (m²)	Coef. k (W/m²K)	Temp/ture difference (°C)	Net losses (Watt)
W1	S			2.86	3.3	9.44	1	9.44	3.21	6.23	0.4	17.00	42.36
O6	S	a		1.44	2.23	3.21	1	3.21		3.21	1.3	17.00	70.94

Thermal Losses Qo		113
Total Increase $Z_D + Z_H$ =	15%	28
Increase due to orientation ZH=	-5	
Increase due to downtimes ZD=	20	

D=Qo/(Fges x Δt)= 113/ (68.5 x 17) = 0.10

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH)		130
CRACK related LOSSES QL = ΣQAi (QAi = axΣIxRxHxΔtxZΓ)=		118.5
Building characterizing num. H=	0.58	
Room characterizing num. R (or r)=	0.9	
Corner windows coef. ZΓ=	1	
LOSSES from AIR CHANGES QL = VxpxcxΔt =		108.6
Volume of space V = 1.6x2.1x3.3=	38	
Number of air changes per hour n =	0.5	
TOTAL of THERMAL LOSSES Q_{tot} = QT + QL		357

Level 1 Room: 15

Name of room BEDROOM 2 – A2 Apartment

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Type of surface	Orientation	Subtracted	Thickness	Length (m)	Height or Width (m)	Surface area (m^2)	Number of surfaces	Subtracted surface area (m^2)	Subtracted surface area (m^2)	Surface area calculated (m^2)	Coef. k (W/m^2K)	Temp/ture difference (°C)	Net losses (W)
W1	S			3.37	3.3	11.12	1	11.12	3.21	7.91	0.4	17.00	53.79
O7	S	a		1.44	2.23	3.21	1	3.21		3.21	1.3	17.00	70.94
W2	E			3.77	3.3	12.44	1	12.44	1.06	11.38	0.5	17.00	96.73
O8	E	a		0.88	1.20	1.06	1	1.06		1.06	1.3	17.00	23.43

Thermal Losses Qo		245
Total Increase $Z_D + Z_H$ =	15%	37
Increase due to orientation ZH=	-5	
Increase due to downtimes ZD=	20	

D=Qo/(Fges x Δt)= 245/ (63.9 x 17) = 0.23

TOTAL THERMAL PERMEABILITY LOSSES QT = Q_O x (1 + ZD + ZH)		282
CRACK related LOSSES QL = ΣQAi (QAi = axΣIxRxHxΔtxZΓ)=		170.0
Building characterizing num. H=	0.58	
Room characterizing num. R (or r)=	0.9	
Corner windows coef. ZΓ=	1	
LOSSES from AIR CHANGES QL = VxρxcxΔt =		99.33
Volume of space V = 3.5x3x3.3=	35	
Number of air changes per hour n =	0.5	
TOTAL of THERMAL LOSSES Q_{tot} = QT + QL		551

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Analytical Results of Cooling Loads Calculation

Level: Level 1
Space: 1
Name: LIVING ROOM DINING – A1

Surfaces

Surface type	Orientation	k (W/m²K)	Length (m)	Height or Width (m)	Surface (m²)	No. of surfaces	Coef, of surface (m²)	Removable surface (m²)	Calculation area (m²)	Interior shading	cantilever shading	Arbitrary shading factor
W1	N	0.4	5.47	3.3	18.05	1	18.05	3.21	14.84		Shade	
O16	N	1.3	1.44	2.23	3.21	1	3.21		3.21	0.25	Shade	
W1	W	0.4	4.88	3.3	16.10	1	16.10	3.21	12.89		Shade	
O1	W	1.3	1.44	2.23	3.21	1	3.21		3.21	0.25	Shade	
W2	S	0.5	1.13	3.3	3.73	1	3.73		3.73		Shade	
W1	W	0.4	3.44	3.3	11.35	1	11.35	3.21	8.14		Shade	
O2	W	1.3	1.44	2.23	3.21	1	3.21		3.21		Shade	
F1	I	2	3.06	4.4	13.46	1	13.46		13.46			

Surface shading factor

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	14.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O16	3.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W1	12.89	0.00	0.00	0.00	0.00	0.06	0.48	0.67	0.79	0.87
O1	3.21	0.00	0.00	0.00	0.00	0.00	0.62	0.90	1.00	1.00
W2	3.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W1	8.14	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.54	0.73
O2	3.21	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.71	0.99
F1	13.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Loads per Surface and hour (Watt)

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	14.84	-1	2	6	16	26	33	40	44	47
O16	3.21	28	33	38	43	47	49	43	36	30
W1	12.89	-1	2	5	14	23	41	60	80	98
O1	3.21	28	33	38	43	47	101	159	182	135
W2	3.73	-0	1	2	5	8	10	13	14	15
W1	8.14	-1	1	3	9	14	18	29	42	56
O2	3.21	48	55	60	65	68	67	161	297	287
F1	13.46	-51	-20	11	44	76	90	76	64	53

Lighting data (Watt)

Type of lighting	Coefficient	Power (W)	Total
Fluorescent in general	1.25	338.4	423

Time schedule of space lighting per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Load	355	355	355	444	444	444	444	444	444

Load data (Watt)

Activity degree	Anticipation factor	Latent factor	Occupants number	Overall anticipation	Overall latent	Total
Sitting light work	70	45	2	140	90	230
Typical office work	75	55	2	150	110	260

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Time schedule of persons per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	0.90	1.00	1.00	1.00	1.00	1.00
Anticipated load	244	244	244	274	305	305	305	305	305
Latent load	168	168	168	189	210	210	210	210	210
Total	412	412	412	463	515	515	515	515	515

Device data (Watt)

Type of device	Anticipation factor	Latent factor	persons number	Overall anticipation	Overall latent	Total
TV	150	0	1	150	0	150

Time schedule of space devices per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sensible load	158	158	158	158	158	158	158	158	158
Latent load	0	0	0	0	0	0	0	0	0
Total	158	158	158	158	158	158	158	158	158

Additional loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Lighting	355	355	355	444	444	444	444	444	444
Persons (sensible)	244	244	244	274	305	305	305	305	305
Persons (Latent)	168	168	168	189	210	210	210	210	210
persons (Overall)	412	412	412	463	515	515	515	515	515
Devices (Anticipated)	158	158	158	158	158	158	158	158	158
Devices (Latent)	0	0	0	0	0	0	0	0	0
Devices (Total)	158	158	158	158	158	158	158	158	158
Cracks	0	0	0	0	0	0	0	0	0

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Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	805	865	919	1115	1217	1315	1487	1665	1627
Latent	168	168	168	189	210	210	210	210	210
Total	973	1033	1087	1304	1427	1525	1697	1875	1837

Device loads due to ventilation per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	66.84	89.81	112.79	136.81	160.83	171.27	160.83	152.06	143.29
Latent	278.32	278.32	278.32	278.32	278.32	278.32	278.32	278.32	278.32
Total	345.16	368.14	391.11	415.13	439.15	449.60	439.15	430.38	421.61

Maximum Device loads due to ventilation (Watt)
Anticipated: 171
Latent: 278
Overall air volume (m^3/h): 62.04

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Level: Level 1
Space: 2
Name: KITCHEN – A1

Surfaces

Surface type	Orientation	k (W/m²K)	Length (m)	Height or Width (m)	Surface (m²)	No. of surfaces	Coef, of surface (m²)	Removable surface (m²)	Calculation area (m²)	Interior shading	cantilever shading	Arbitrary shading factor
W2	W	0.5	1.6	3.3	5.28	1	5.28		5.28		shade	
W1	N	0.4	2.69	3.3	8.88	1	8.88	1.37	7.51		shade	
O15	N	1.3	1.44	0.95	1.37	1	1.37		1.37	0.56	shade	

Surface shading factor

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W2	5.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.43
W1	7.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O15	1.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Loads per Surface and hour (Watt)

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W2	5.28	-1	1	2	7	12	15	18	20	35
W1	7.51	-1	1	3	8	13	17	20	22	24
O15	1.37	19	22	24	26	27	27	23	18	13

Lighting data (Watt)

Type of lighting	Coefficient	Power (W)	Total
Fluorescence in general	1.25	101.52	126.9

Time schedule of space lighting per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm

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Time schedule	0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Load	107	107	107	133	133	133	133	133	133

People's data (Watt)

Activity degree	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
Sitting light work	70	45	1	70	45	115
Typical office work	75	55	2	75	55	130

Time schedule of space persons per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	0.90	1.00	1.00	1.00	1.00	1.00
Anticipated load	122	122	122	137	152	152	152	152	152
Latent load	84	84	84	95	105	105	105	105	105
Total	206	206	206	232	257	257	257	257	257

Device data (Watt)

Type of device	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
Refrigerator	200	0	1	200	0	200
Electric Oven	1000	250	1	1000	250	1250

Time schedule of space devices per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Anticipated load	1260	1260	1260	1260	1260	1260	1260	1260	1260
Latent load	263	263	263	263	263	263	263	263	263
Total	1523	1523	1523	1523	1523	1523	1523	1523	1523

Additional loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Lighting	107	107	107	133	133	133	133	133	133

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Persons (Anticipated)	122	122	122	137	152	152	152	152	152
Persons (Latent)	84	84	84	95	105	105	105	105	105
Persons (Overall)	206	206	206	232	257	257	257	257	257
Devices (Anticipated)	1260	1260	1260	1260	1260	1260	1260	1260	1260
Devices (Latent)	263	263	263	263	263	263	263	263	263
Devices (Total)	1523	1523	1523	1523	1523	1523	1523	1523	1523
Cracks	0	0	0	0	0	0	0	0	0

Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	1506	1513	1518	1572	1598	1604	1607	1605	1618
Latent	347	347	347	357	368	368	368	368	368
Total	1853	1859	1864	1929	1965	1972	1974	1973	1985

Device loads due to ventilation per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	60.15	80.83	101.51	123.13	144.75	154.15	144.75	136.85	128.96
Latent	250.49	250.49	250.49	250.49	250.49	250.49	250.49	250.49	250.49
Total	310.64	331.32	352.00	373.62	395.24	404.64	395.24	387.34	379.45

Maximum Device loads due to ventilation (Watt)

Anticipated: 154

Latent: 250
Overall air volume (m³/h): 55.84
Level: Level 1
Space: 3
Name: BEDROOM 1 – A1

Surfaces

Surface type	Orientation	k (W/m²K)	Length (m)	Height or Width (m)	Surface (m²)	No. of surfaces	Coef, of surface (m²)	Removable surface (m²)	Calculation area (m²)	Interior shading	cantilever shading	Arbitrary shading factor
W1	0.4	3.84	3.3	12.67	1	12.67	3.21	9.46		0.4	shade	
O14	1.3	1.44	2.23	3.21	1	3.21		3.21	0.56	1.3	shade	

Surface shading factor

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	9.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O14	3.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Loads per Surface and hour (Watt)

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	9.46	-1	2	4	10	17	21	25	28	30
O14	3.21	45	52	56	61	64	64	55	42	30

Lighting data (Watt)

Type of lighting	Coefficient	Power (W)	Total
Fluorescent in general	1.25	119.88	149.85

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Time schedule of space lighting per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Load	126	126	126	157	157	157	157	157	157

People's data (Watt)

Activity degree	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
Sitting light work	70	45	1	70	45	115
Typical office work	70	45	1	70	45	115

Time schedule of space persons per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	0.90	1.00	1.00	1.00	1.00	1.00
Anticipated load	118	118	118	132	147	147	147	147	147
Latent load	76	76	76	85	95	95	95	95	95
Total	193	193	193	217	242	242	242	242	242

Device data (Watt)

Type of device	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
TV	150	0	1	150	0	150

Time schedule of space devices per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Anticipated load	158	158	158	158	158	158	158	158	158
Latent load	0	0	0	0	0	0	0	0	0
Total	158	158	158	158	158	158	158	158	158

Additional loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Lighting	126	126	126	157	157	157	157	157	157

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Persons (Anticipated)	118	118	118	132	147	147	147	147	147
Persons (Latent)	76	76	76	85	95	95	95	95	95
Persons (Overall)	193	193	193	217	242	242	242	242	242
Devices (Anticipated)	158	158	158	158	158	158	158	158	158
Devices (Latent)	0	0	0	0	0	0	0	0	0
Devices (Total)	158	158	158	158	158	158	158	158	158
Cracks	0	0	0	0	0	0	0	0	0

Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	445	454	461	519	543	547	542	531	522
Latent	76	76	76	85	95	95	95	95	95
Total	520	530	536	604	637	641	637	626	617

Device loads due to ventilation per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	23.68	31.82	39.96	48.47	56.97	60.67	56.97	53.87	50.76
Latent	98.60	98.60	98.60	98.60	98.60	98.60	98.60	98.60	98.60
Total	122.27	130.41	138.55	147.06	155.57	159.27	155.57	152.46	149.36

Maximum Device loads due to ventilation (Watt)
Anticipated: 61
Latent: 99
Overall air volume (m^3/h): 21.98

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Level: Level 1
Space: 4
Name: OFFICE ROOM – A1

Surfaces

Surface type	Orientation	k (W/m²K)	Length (m)	Height or Width (m)	Surface (m²)	No. of surfaces	Coef, of surface (m²)	Removable surface (m²)	Calculation area (m²)	Interior shading	cantilever shading	Arbitrary shading factor
W1	N	0.4	4.14	3.3	13.66	1	13.66	3.21	10.45		shade	
O13	N	1.3	1.44	2.23	3.21	1	3.21		3.21	0.56	shade	
W2	E	0.5	4.21	3.3	13.89	1	13.89	1.74	12.15			
O12	E	1.3	1.45	1.20	1.74	1	1.74		1.74	0.56		

Surface shading factor

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	10.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O13	3.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W2	12.15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
O12	1.74	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Loads per Surface and hour (Watt)

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	10.45	-1	2	4	11	18	23	28	31	33
O13	3.21	45	52	56	61	64	64	55	42	30
W2	12.15	87	91	91	61	49	48	47	50	54
O12	1.74	126	60	31	33	35	35	30	23	16

Lighting data (Watt)

Type of lighting	Coefficient	Power (W)	Total
Fluorescent in general	1.25	133.38	166.725

Time schedule of space lighting per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Load	140	140	140	175	175	175	175	175	175

People’s data (Watt)

Activity degree	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
Sitting light work	70	45	1	70	45	115
Sitting light work	70	45	1	70	45	115

Time schedule of space persons per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	0.90	1.00	1.00	1.00	1.00	1.00
Anticipated load	118	118	118	132	147	147	147	147	147
Latent load	76	76	76	85	95	95	95	95	95
Total	193	193	193	217	242	242	242	242	242

Additional loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Lighting	140	140	140	175	175	175	175	175	175
Persons (Anticipated)	118	118	118	132	147	147	147	147	147
Persons (Latent)	76	76	76	85	95	95	95	95	95
Persons (Overall)	193	193	193	217	242	242	242	242	242
Devices (Anticipated)	0	0	0	0	0	0	0	0	0

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Devices (Latent)	0	0	0	0	0	0	0	0	0
Devices (Total)	0	0	0	0	0	0	0	0	0
Cracks	0	0	0	0	0	0	0	0	0

Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	514	461	440	474	489	492	482	467	456
Latent	76	76	76	85	95	95	95	95	95
Total	590	537	515	559	583	586	576	561	550

Device loads due to ventilation per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Sensible	26.34	35.40	44.46	53.92	63.39	67.51	63.39	59.93	56.48
Latent	109.70	109.70	109.70	109.70	109.70	109.70	109.70	109.70	109.70
Total	136.04	145.10	154.16	163.62	173.09	177.21	173.09	169.63	166.18

Maximum Device loads due to ventilation (Watt)
Sensible: 68
Latent: 110
Overall air volume (m^3/h): 24.45

Level: Level 1
Space: 5
Name: HALL / LIVING ROOM – A2

Surfaces

Surface type	Orientation	k (W/m²K)	Length (m)	Height or Width (m)	Surface (m²)	No. of surfaces	Coef, of surface (m²)	Removable surface (m²)	Calculation area (m²)	Interior shading	cantilever shading	Arbitrary shading factor
W1	W	0.4	4.38	3.3	14.45	1	14.45	3.21	11.24		shade	

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O3	W	1.3	1.44	2.23	3.21	1	3.21		3.21	0.25	shade	
W1	S	0.4	4.73	3.3	15.61	1	15.61	3.21	12.40		Shade	
O4	S	1.3	1.44	2.23	3.21	1	3.21		3.21	0.25	Shade	
W2	W	0.5	0.76	3.3	2.51	1	2.51		2.51		Shade	
W1	S	0.4	1.27	3.3	4.19	1	4.19		4.19		Shade	
I1	I	1.8	1.57	3.3	5.18	1	5.18		5.18			
I1	I	1.8	1.56	3.3	5.15	1	5.15	2.10	3.05			
O17	I	3.48	1	2.1	2.10	1	2.10		2.10			
F1	I	2	5.21	1.76	9.17	1	9.17		9.17			

Surface shading factor

Surface type	Calculation area (m^2)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	11.24	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.54	0.73
O3	3.21	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.71	0.99
W1	12.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O4	3.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W2	2.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.48
W1	4.19	0.00	0.01	0.10	0.10	0.02	0.00	0.00	0.00	0.00
I1	5.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I1	3.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O17	2.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
F1	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Loads per Surface and hour (Watt)

Surface type	Calculation area (m^2)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	11.24	-1	2	4	12	20	25	39	58	77
O3	3.21	28	33	38	43	47	49	85	139	134
W1	12.40	-1	2	5	13	22	28	33	36	40
O4	3.21	28	33	38	43	47	49	43	36	30
W2	2.51	-0	1	1	3	6	7	8	11	18
W1	4.19	-0	1	2	6	8	9	11	12	13

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I1	5.18	-18	-7	4	15	26	31	26	22	18
I1	3.05	-10	-4	2	9	16	18	16	13	11
O17	2.10	-14	-5	3	12	21	25	21	17	14
F1	9.17	-35	-13	8	30	52	62	52	44	36

Lighting data (Watt)

Type of lighting	Coefficient	Power (W)	Total
Fluorescence in general	1.25	288	360

Time schedule of space lighting per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Load	302	302	302	378	378	378	378	378	378

People’s data (Watt)

Activity degree	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
Sitting light work	70	45	2	140	90	230
Typical office work	75	55	2	150	110	260

Time schedule of persons in space per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	0.90	1.00	1.00	1.00	1.00	1.00
Anticipated load	244	244	244	274	305	305	305	305	305
Latent load	168	168	168	189	210	210	210	210	210
Total	412	412	412	463	515	515	515	515	515

Device data (Watt)

Type of device	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
TV	150	0	1	150	0	150

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Time schedule of space devices per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Anticipated load	158	158	158	158	158	158	158	158	158
Latent load	0	0	0	0	0	0	0	0	0
Total	158	158	158	158	158	158	158	158	158

Additional loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Lighting	302	302	302	378	378	378	378	378	378
Persons (Anticipated)	244	244	244	274	305	305	305	305	305
Persons (Latent)	168	168	168	189	210	210	210	210	210
Persons (Overall)	412	412	412	463	515	515	515	515	515
Devices (Anticipated)	158	158	158	158	158	158	158	158	158
Devices (Latent)	0	0	0	0	0	0	0	0	0
Devices (Total)	158	158	158	158	158	158	158	158	158
Cracks	0	0	0	0	0	0	0	0	0

Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	680	746	809	997	1104	1142	1176	1230	1231
Latent	168	168	168	189	210	210	210	210	210
Total	848	914	977	1186	1314	1352	1386	1440	1441

Device loads due to ventilation per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm

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Anticipated	56.88	76.44	95.99	116.43	136.88	145.76	136.88	129.41	121.94
Latent	236.87	236.87	236.87	236.87	236.87	236.87	236.87	236.87	236.87
Total	293.75	313.31	332.86	353.30	373.75	382.63	373.75	366.28	358.81

Maximum Device loads due to ventilation (Watt)
Anticipated: 146
Latent: 237
Overall air volume (m³/h): 52.80

Level: Level 1
Space: 6
Name: KITCHEN – A2

Surfaces

Surface type	Orientation	k (W/m²K)	Length (m)	Height or Width (m)	Surface (m²)	No. of surfaces	Coef, of surface (m²)	Removable surface (m²)	Calculation area (m²)	Interior shading	cantilever shading	Arbitrary shading factor
W1	S	0.4	2.78	3.3	9.17	1	9.17	3.21	5.96		Shade	
O5	S	1.3	1.44	2.23	3.21	1	3.21		3.21	0.56	shade	

Surface shading factor

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	5.96	0.00	0.01	0.10	0.10	0.02	0.00	0.00	0.00	0.00
O5	3.21	0.00	0.00	0.05	0.06	0.00	0.00	0.00	0.00	0.00

Loads per Surface and hour (Watt)

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	5.96	-1	1	3	8	11	13	16	17	19
O5	3.21	45	52	67	73	64	64	55	42	30

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958218

Lighting data (Watt)

Type of lighting	Coefficient	Power (W)	Total
Fluorescence in general	1.25	72	90

Time schedule of space lighting per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Load	76	76	76	95	95	95	95	95	95

People's data (Watt)

Activity degree	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
Sitting light work	70	45	1	70	45	115
Standing light work	75	55	1	75	55	130

Time schedule of persons in space per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	0.90	1.00	1.00	1.00	1.00	1.00
Anticipated load	122	122	122	137	152	152	152	152	152
Latent load	84	84	84	95	105	105	105	105	105
Total	206	206	206	232	257	257	257	257	257

Device data (Watt)

Type of device	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
Refrigerator	200	0	1	200	0	200
Electric Oven	1000	250	1	1000	250	1250

Time schedule of space devices per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Anticipated load	1260	1260	1260	1260	1260	1260	1260	1260	1260
Latent load	263	263	263	263	263	263	263	263	263
Total	1523	1523	1523	1523	1523	1523	1523	1523	1523

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Additional loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Lighting	76	76	76	95	95	95	95	95	95
Persons (Anticipated)	76	76	76	95	95	95	95	95	95
Persons (Latent)	122	122	122	137	152	152	152	152	152
Persons (Overall)	84	84	84	95	105	105	105	105	105
Devices (Anticipated)	206	206	206	232	257	257	257	257	257
Devices (Latent)	1260	1260	1260	1260	1260	1260	1260	1260	1260
Devices (Total)	263	263	263	263	263	263	263	263	263
Cracks	1523	1523	1523	1523	1523	1523	1523	1523	1523

Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	1501	1510	1528	1573	1582	1584	1578	1566	1556
Latent	347	347	347	357	368	368	368	368	368
Total	1848	1856	1875	1930	1949	1952	1945	1933	1923

Device loads due to ventilation per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	42.66	57.33	71.99	87.33	102.66	109.32	102.66	97.06	91.46
Latent	177.65	177.65	177.65	177.65	177.65	177.65	177.65	177.65	177.65
Total	220.32	234.98	249.65	264.98	280.31	286.98	280.31	274.71	269.11

Maximum Device loads due to ventilation (Watt)
Anticipated: 109
Latent: 178
Overall air volume (m^3/h): 39.60

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958218

Level: Level 1
Space: 7
Name: BEDROOM 1 – A2

Surfaces

Surface type	Orientation	k (W/m²K)	Length (m)	Height or Width (m)	Surface (m²)	No. of surfaces	Coef, of surface (m²)	Removable surface (m²)	Calculation area (m²)	Interior shading	cantilever shading	Arbitrary shading factor
W1	S	0.4	2.86	3.3	9.44	1	9.44	3.21	6.23		Shade	
O6	S	1.3	1.44	2.23	3.21	1	3.21		3.21	0.56	shade	

Surface shading factor

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	6.23	0.00	0.01	0.10	0.10	0.02	0.00	0.00	0.00	0.00
O6	3.21	0.00	0.00	0.05	0.06	0.00	0.00	0.00	0.00	0.00

Loads per Surface and hour (Watt)

Surface type	Calculation area (m²)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	6.23	-1	1	4	9	11	14	17	18	20
O6	3.21	45	52	67	73	64	64	55	42	30

Lighting data (Watt)

Type of lighting	Coefficient	Power (W)	Total
Fluorescence in general	1.25	103.32	129.15

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958218

Time schedule of space lighting per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Load	108	108	108	136	136	136	136	136	136

People's data (Watt)

Activity degree	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
Sitting light work	70	45	2	140	90	230

Time schedule of persons in space per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	0.90	1.00	1.00	1.00	1.00	1.00
Anticipated load	118	118	118	132	147	147	147	147	147
Latent load	76	76	76	85	95	95	95	95	95
Total	193	193	193	217	242	242	242	242	242

Device data (Watt)

Type of device	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
TV	150	0	1	150	0	150

Time schedule of space devices per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Anticipated load	158	158	158	158	158	158	158	158	158
Latent load	0	0	0	0	0	0	0	0	0
Total	158	158	158	158	158	158	158	158	158

Additional loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Lighting	99	99	99	124	124	124	124	124	124
Persons (Anticipated)	118	118	118	132	147	147	147	147	147

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958218

Persons (Latent)	76	76	76	85	95	95	95	95	95
Persons (Overall)	193	193	193	217	242	242	242	242	242
Devices (Anticipated)	158	158	158	158	158	158	158	158	158
Devices (Latent)	0	0	0	0	0	0	0	0	0
Devices (Total)	158	158	158	158	158	158	158	158	158
Cracks	0	0	0	0	0	0	0	0	0

Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	576	549	550	575	574	576	567	554	544
Latent	76	76	76	85	95	95	95	95	95
Total	652	624	626	660	669	671	661	648	639

Device loads due to ventilation per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	18.67	25.08	31.50	38.20	44.91	47.83	44.91	42.46	40.01
Latent	77.72	77.72	77.72	77.72	77.72	77.72	77.72	77.72	77.72
Total	96.39	102.80	109.22	115.93	122.64	125.55	122.64	120.19	117.74

Maximum Device loads due to ventilation (Watt)
Anticipated: 48
Latent: 78
Overall air volume (m^3/h): 17.32

Level: Level 1
Space: 8
Name: BEDROOM 2 – A2

Surfaces

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958218

Surface type	Orientation	k (W/m^2K)	Length (m)	Height or Width (m)	Surface (m^2)	No. of surfaces	Coef, of surface (m^2)	Removable surface (m^2)	Calculation area (m^2)	Interior shading	cantilever shading	Arbitrary shading factor
W1	S	0.4	3.37	3.3	11.12	1	11.12	3.21	7.91		Shade	
O7	S	1.3	1.44	2.23	3.21	1	3.21		3.21	0.56	shade	
W2	E	0.5	3.77	3.3	12.44	1	12.44	1.06	11.38			
O8	E	1.3	0.88	1.20	1.06	1	1.06		1.06	0.56		

Surface shading factor

Surface type	Calculation area (m^2)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	7.91	0.00	0.01	0.10	0.10	0.02	0.00	0.00	0.00	0.00
O7	3.21	0.00	0.00	0.05	0.06	0.00	0.00	0.00	0.00	0.00
W2	11.38	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
O8	1.06	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Loads per Surface and hour (Watt)

Surface type	Calculation area (m^2)	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
W1	7.91	-1	1	5	11	14	18	21	23	25
O7	3.21	45	52	67	73	64	64	55	42	30
W2	11.38	82	85	85	57	46	45	44	47	50
O8	1.06	76	36	19	20	21	21	18	14	10

Lighting data (Watt)

Type of lighting	Coefficient	Power (W)	Total
Fluorescence in general	1.25	94.5	118.125

Time schedule of space lighting per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Load	99	99	99	124	124	124	124	124	124

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People's data (Watt)

Activity degree	Anticipation factor	Latent factor	Persons number	Overall anticipation	Overall latent	Total
Sitting light work	70	45	2	140	90	230

Time schedule of persons in space per hour

Title	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Time schedule	0.80	0.80	0.80	0.90	1.00	1.00	1.00	1.00	1.00
Anticipated load	118	118	118	132	147	147	147	147	147
Latent load	76	76	76	85	95	95	95	95	95
Total	193	193	193	217	242	242	242	242	242

Additional loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Lighting	108	108	108	136	136	136	136	136	136
Persons (Anticipated)	118	118	118	132	147	147	147	147	147
Persons (Latent)	76	76	76	85	95	95	95	95	95
Persons (Overall)	193	193	193	217	242	242	242	242	242
Devices (Anticipated)	0	0	0	0	0	0	0	0	0
Devices (Latent)	0	0	0	0	0	0	0	0	0
Devices (Total)	0	0	0	0	0	0	0	0	0
Cracks	0	0	0	0	0	0	0	0	0

Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	270	279	297	350	358	361	354	342	333
Latent	76	76	76	85	95	95	95	95	95
Total	346	354	373	435	453	455	449	437	427

Device loads due to ventilation per hour (Watt)

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Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	20.41	27.42	34.44	41.77	49.10	52.29	49.10	46.43	43.75
Latent	84.98	84.98	84.98	84.98	84.98	84.98	84.98	84.98	84.98
Total	105.38	112.40	119.41	126.75	134.08	137.27	134.08	131.40	128.72

Maximum Device loads due to ventilation (Watt)
Anticipated: 52
Latent: 85
Overall air volume (m^3/h): 18.94

Space: 1
Name: DINING ROOM – A1
Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	805	865	919	1115	1217	1315	1487	1665	1627
Latent	168	168	168	189	210	210	210	210	210
Total	973	1033	1087	1304	1427	1525	1697	1875	1837

Space: 2
Name: KITCHEN – A1
Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	1506	1513	1518	1572	1598	1604	1607	1605	1618
Latent	347	347	347	357	368	368	368	368	368
Total	1853	1859	1864	1929	1965	1972	1974	1973	1985

Space: 3
Name: BEDROOM 1 – A1
Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	445	454	461	519	543	547	542	531	522
Latent	76	76	76	85	95	95	95	95	95
Total	520	530	536	604	637	641	637	626	617

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Space: 4
Name: OFFICE ROOM – A1
Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	514	461	440	474	489	492	482	467	456
Latent	76	76	76	85	95	95	95	95	95
Total	590	537	515	559	583	586	576	561	550

Space: 5
Name: HALL / LIVING ROOM – A2
Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	680	746	809	997	1104	1142	1176	1230	1231
Latent	168	168	168	189	210	210	210	210	210
Total	848	914	977	1186	1314	1352	1386	1440	1441

Space: 6
Name: KITCHEN – A2
Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	1501	1510	1528	1573	1582	1584	1578	1566	1556
Latent	347	347	347	357	368	368	368	368	368
Total	1848	1856	1875	1930	1949	1952	1945	1933	1923

Space: 7
Name: BEDROOM 1 – A2
Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	576	549	550	575	574	576	567	554	544
Latent	76	76	76	85	95	95	95	95	95

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Total	652	624	626	660	669	671	661	648	639

Space: 8
Name: BEDROOM 2 -A2
Overall space loads per hour (Watt)

Type of load	10 am	11 am	12 am	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Anticipated	576	549	550	575	574	576	567	554	544
Latent	76	76	76	85	95	95	95	95	95
Total	652	624	626	660	669	671	661	648	639

OVERALL BUILDING LOADS FOR EVERY MONTH AND HOUR WITHOUT VENTILATION (KW)

HOURS	10	11	12	13	14	15	16	17	18
21 MAY	6	6	7	7	8	8	8	8	8
21 JUNE.	7	7	7	8	8	9	9	9	9
23 JULY.	8	8	8	9	9	9	9	9	9
24 AUG.	8	8	8	9	9	9	9	10	9
22 SEPT.	7	8	8	9	9	9	9	9	9

MAXIMUM SPACE LOADS WITH VENTILATION

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Level	Space	System	Surface area (m²)	Max load time	Exterior air (m3/h)	Total load (with ventilation) (Watt)	Total anticipated load (with ventilation) (Watt)	Total latent load φορτίο (with ventilation) (Watt)	Anticipated load per m² (Watt/m²)	Total load per m² (Watt/m²)
Level 1	LIVING ROOM-A1	1	37.6	17	62.0	2305.6	1817.3	488.3	48.3	61.3
Level 1	KITCHEN-A1	1	11.3	15	55.8	2376.3	1758.3	618.0	155.9	210.7
Level 1	BEDROOM 1 – A1	1	13.3	15	22.0	800.7	607.6	193.1	45.6	60.1
Level 1	BEDROOM 2 – A1	1	14.8	15	24.5	763.5	559.3	204.2	37.7	51.5
Level 1	HALL / LIVING ROOM-A2	2	32.0	17	52.8	1805.9	1359.0	446.9	42.5	56.4
Level 1	KITCHEN-A2	2	8.0	15	39.6	2238.6	1693.4	545.2	211.7	279.8
Level 1	BEDROOM 1 – A2	2	11.5	15	18.9	592.3	412.8	179.5	36.0	51.6
Level 1	BEDROOM 2 – A2	2	10.5	15	17.3	796.1	623.8	172.2	59.4	75.8
Total			139.0		293.0	11679.0	8831.6	2847.3	63.5	84.0

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6.2 Czech demonstration building

Meander properties

The following tables show the properties of all meanders for the Czech building. They contain the name of the distribution bar, the loop identification, the length of the meanders, the length of the meanders supply line on the outside of the building and on the inside until the circuit manifold (distribution bar) Furthermore, the flowrate is given based on the simulations results from chapter Heating loads calculation (2.2.2). The name of the distribution bar is composed as follows: The first letter is a D for distribution, followed by the floor assignment (Gf for ground floor, 1f for first floor), followed by Ex or In. These show whether the distribution beam supplies internal heating (In) elements or external (Ex) ones. The last letter indicates the cardinal direction. The “Loop naming code” is similar. First comes an L for loop, then the floor designation (Gf for ground floor and 1f for first floor), followed by the rooms that are heated by the meander. Small loops at façade modules with little height (at the very bottom or top of the façade) are only given a letter for the cardinal direction and a number. Counting starts from the north and goes counter clockwise. These numbers are also given to loops that heat the same room.

TABLE 6.2: MEANDER PROPERTIES EAST SIDE.

Distribution bar	Loop	Length [m]	Supply line Ex [m]	Supply-Line In [m]	Total length [m]	Flow-Rate [kg/h]
DGfExE	LGfE1+Hall	18.5	0	5.6	24.1	18
DGfExE	LGfE2	18.5	0	5.6	24.1	23
DGfExE	LGfBedN3+Hall	65	0	5.6	70.6	79
DGfExE	LGfBedE1	40	0	5.6	45.6	50
DGfExE	LGfBedE2	40	0	5.6	45.6	50
D1fInE	L1fBedE1	52	0	15.4	67.4	32
D1fInE	L1fBedE2	52	0	15.4	67.4	32
D1fInE	L1fBedE3	33	0	15.4	48.4	21

TABLE 6.3: MEANDER PROPERTIES NORTH SIDE.

Distribution bar	Loop	Length [m]	Supply line Ex [m]	Supply-Line In [m]	Total length [m]	Flow-Rate [kg/h]
DGfExN	LGfN1	15.5	0	5.6	21.1	28
DGfExN	LGfN2	26.8	0	5.6	32.4	32
DGfExN	LGfHall	26.4	0	5.6	32	40
DGfExN	LGfWC	39.3	0	5.6	44.9	25
DGfExN	LGfBath	40.3	0	5.6	45.9	39
DGfExN	LGfBedN1	50.4	0	5.6	56	52
DGfExN	LGfBedN2	48.6	0	5.6	54.2	41

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D1fExN	**L1fWC+1fHall**	42.3	0	13.6	55.9	52
D1fExN	**L1fBath**	67.4	0	13.6	81	56
D1fExN	**L1fN**	21	0	13.6	34.6	15

TABLE 6.4: MEANDER PROPERTIES WEST SIDE.

Distribution bar	Loop	Length [m]	Supply line Ex [m]	Supply-Line In [m]	Total length [m]	Flow-Rate [kg/h]
DGfExS	**LGfW1**	21	15	2.6	38.6	29
DGfExS	**LGfLivS3**	37	15	2.6	54.6	51
DGfExS	**LGfLivS4**	37	15	2.6	54.6	51
D1fInW	**L1fLivS2**	38	0	2	40	56
D1fInW	**L1fW**	9.3	0	2	11.3	14

TABLE 6.5: MEANDER PROPERTIES SOUTH SIDE.

Distribution bar	Loop	Length [m]	Supply line Ex [m]	Supply-Line In [m]	Total length [m]	Flow-Rate [kg/h]
DGfExS	**LGfS2**	26.7	6	2.6	32.7	37
DGfExS	**LGfS1**	26.7	6	2.6	32.7	36
DGfExS	**LGfBedE3**	57	0	2.6	57	71
DGfExS	**LGfBedS**	23.8	0	2.6	23.8	25
DGfExS	**LGfLivS1**	40.9	0	2.6	40.9	56
DGfExS	**LGfLivS2**	40.9	0	2.6	40.9	56
D1fExS	**L1fBedS**	48.4	0	3.6	48.4	45
D1fExS	**L1fLivS1**	23.8	0	3.6	23.8	35
D1fExS	**L1fs**	21	0	3.6	21	35

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6.3 Heat Pump Specifications

6.3.1 Greek demonstration heat pump (DAIKIN EBLA09D3V3) specifications

Technical specifications					EBLA09D3V3	EBLA11D3V3	EBLA14D3V3	EBLA16D3V3
Heating capacity	Nom.			kW	9.37 (1) / 9.00 (2)	10.6 (1) / 9.82 (2)	12.0 (1) / 12.5 (2)	16.0 (1) / 16.0 (2)
Cooling capacity	Nom.			kW	9.35 (3) / 9.10 (4)	11.6 (3) / 11.5 (4)	12.8 (3) / 12.7 (4)	14.0 (3) / 15.3 (4)
Heater capacity	Step 1			kW	3			
Power input	Cooling	Nom.		kW	2.79 (3) / 1.71 (4)	3.56 (3) / 2.17 (4)	4.06 (3) / 2.51 (4)	4.58 (3) / 3.24 (4)
	Heating	Nom.		kW	1.91 (1) / 2.43 (2)	2.18 (1) / 2.68 (2)	2.46 (1) / 3.42 (2)	3.53 (1) / 4.56 (2)
COP					4.91 (1) / 3.71 (2)	4.83 (1) / 3.66 (2)	4.87 (1) / 3.64 (2)	4.53 (1) / 3.51 (2)
EER					3.35 (3) / 5.34 (4)	3.26 (3) / 5.31 (4)	3.16 (3) / 5.04 (4)	3.06 (3) / 4.74 (4)
SEER					5.62 (5)	5.79 (5)	5.71 (5)	5.59 (5)
Casing	Colour				Silver			
	Material				Polyester painted galvanised steel plate			
Dimensions	Unit	Height		mm	870			
		Width		mm	1,380			
		Depth		mm	460			
	Packed unit	Height		mm	1,053			
		Width		mm	1,520			
		Depth		mm	650			
Weight	Unit			kg	149			
	Packed unit			kg	166			
Packing	Material				PE wrapping foil / Carton / Wood (pallet)			
	Weight			kg	17			
Heat exchanger	Length			mm	1,136 / 1,166 / 1,195			
	Rows	Quantity			3			
	Fin pitch			mm	1.4			
	Passes	Quantity			14			
	Face area			m^2	0.950 /0.970 /1.00			
	Stages	Quantity			38			
	Tube type				7.0 Hi-XD			
	Fin	Type			WF fin			
		Treatment			Anti-corrosion treatment			
Fan	Type				Propeller fan			
	Quantity				1			
	Discharge direction				Horizontal			
	Air flow rate	Heating	High	m^3/min	48.0	55.8	70.4	85.0
		Cooling	High	m^3/min	63.1	70.4	85.0	
Fan motor	Quantity				1			
	Model				Brushless DC motor			
Fan motor	Speed	Steps			8			
		Heating	Nom.	rpm	400	450	550	650
		Cooling	Nom.	rpm	500	550	650	
	Output			W	230			
	Drive				Direct drive			
Compressor	Quantity				1			
	Model				2Y350BPAX1P#C			
	Type				Hermetically sealed swing compressor			
PED	Category				Category II			
	Most critical part	Name			Accumulator			
		Ps*V		Bar*l	159			
Operation range	Heating	Ambient	Min.	°CDB	-25			
			Max.	°CDB	35			
		Water side	Min.	°C	15 (6)			
			Max.	°C	60 (6)			
	Cooling	Ambient	Min.	°CDB	10			
			Max.	°CDB	43			
		Water side	Min.	°C	5			
			Max.	°C	22			
	Domestic hot water	Ambient	Min.	°CDB	-25			
			Max.	°CDB	35			
		Water side	Min.	°C	25			
			Max.	°C	55 (6)			

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Refrigerant	Type				R-32			
	GWP				675.0			
	Charge			kg	3.80			
	Charge			TCO2Eq	2.57			
	Control				Expansion valve			
	Circuits	Quantity			1			
Refrigerant oil	Type				FW68DA			
	Charged volume			l	135			
Defrost method					Reversed cycle			
Defrost control					Sensor for outdoor heat exchanger temperature			
Capacity control	Method				Inverter controlled			
Safety devices	Item	01			High pressure switch			
		02			Low pressure switch			
		03			Fan driver overload protector			
Safety devices	Item	04			Fuse			
		05			Compressor motor thermal protector			
Pump	Quantity				1			
	Nr of speeds				PWM			
	Nominal ESP unit	Heating		kPa	106.9	102.7	96.5	71.4
		Cooling		kPa	107.0	98.4	92.3	85.5
	Power input			W	180			
Water side Heat exchanger	Type				Plate heat exchanger			
	Quantity				1			
	Water volume			l	2.16			
	Water flow rate	Heating	Nom.	l/min	26.9 (1) / 25.8 (2)	30.3 (1) / 28.2 (2)	34.4 (1) / 35.7 (2)	45.9 (1) / 45.9 (2)
		Cooling	Nom.	l/min	26.8 (3) / 26.1 (4)	33.2 (3) / 33.0 (4)	36.8 (3) / 36.3 (4)	40.2 (3) / 43.9 (4)
	Insulation material				EPDM type			
	Heater			W	50.0			
Expansion vessel	Volume			l	8			
	Max. water pressure			bar	4			
	Pre pressure			bar	1			
	Heater			W	65			
Water filter	Diameter perforations			mm	0.8			
	Material				Stainless steel			
Water circuit	Piping connections diameter			inch	G 1" (male)			
	Piping			inch	1-1/4"			
	Piping length	Max.	OU - Tank	m	10			
	Level dif- ference	Max.		m	5			
	Safety valve			bar	3			
	Drain valve / fill valve				Yes			
	Shut off valve				Yes			
	Air purge valve				Yes			
	Minimum water volume in the system			l	20 (7)			
	Heater			W	66.0			
General	Supplier/ Manu- facturer details	Name and address			Daikin Europe N.V. - Zandvoordestraat 300, 8400 Oostende, Belgium			
		Name or trademark			Daikin Europe N.V.			
	Product descrip- tion	Air-to-water heat pump			Yes			
		Brine-to-water heat pump			No			
		Heat pump combination heater			No			
		Low-temperature heat pump			No			
		Supplementary heater integrated			Yes			
General	Product descrip- tion	Water-to-water heat pump			No			
LW(A) Sound power level (according to EN14825)				dB(A)	62.0			
Sound condition Ecodesign and energy label					Sound power in heating mode, measured according to the EN12102 under conditions of the EN14825			
Space heating general	Air to water unit	Rated airflow (outdoor)		m^3/h	2,880	3,350	4,220	5,100
	Other	Capacity control			Inverter			
		Pck (Crankcase heater mode)		kW	0.000			
		Poff (Off mode)		kW	0.023			
		Psb (Standby mode)		kW	0.023			
		Pto (Thermostat off)		kW	0.023			
	Inte- grated supple- mentary heater	Type of energy input			Electrical			

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Technical specifications					EBLA09D3V3	EBLA11D3V3	EBLA14D3V3	EBLA16D3V3
Space heating	Average climate water outlet 55°C	General	Annual energy consumption	kWh	5,404	6,134	6,651	7,359
			ηs (Seasonal space heating efficiency)	%	135	132	134	132
			Prated at -10°C	kW	9.0	10.0	11.0	12.0
			Qhe Annual energy consumption (GCV)	Gj	19	22	24	26
			SCOP		3.44	3.37	3.42	3.37
			Seasonal space heating eff. class		A++			
		A Condition (-7°CDB/-8°CWB)	Cdh (Degradation heating)		1.0			
			COPd		2.09	1.90	2.02	1.95
			Pdh	kW	8.5	9.3	9.4	
			PERd	%	83.6	76.0	80.8	78.0
		B Condition (2°CDB/1°CWB)	Cdh (Degradation heating)		1.0			
			COPd		3.28	3.25	3.28	3.27
			Pdh	kW	5.0	5.4	6.2	6.9
			PERd	%	131.2	130.0	131.2	130.8
		C Condition (7°CDB/6°CWB)	Cdh (Degradation heating)		1.0			
			COPd		4.80	4.81	4.88	4.93
			Pdh	kW	4.4			
			PERd	%	192.0	192.4	195.2	197.2
		D Condition (12°CDB/11°CWB)	Cdh (Degradation heating)		1.0			
			COPd		6.45	6.41	6.58	6.60
			Pdh	kW	5.3			
			PERd	%	258.0	256.4	263.2	264.0
		Tol (temperature operating limit)	COPd		1.70	1.64	1.70	1.67
			Pdh	kW	6.8	7.6	7.8	8.0
			PERd	%	68.0	65.6	68.0	66.8
			TOL	°C	-10			
			WTOL	°C	55			

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Technical specifications					EBLA09D3V3	EBLA11D3V3	EBLA14D3V3	EBLA16D3V3
Space heating	Average climate water outlet 55°C	Rated heat output supplementary capacity	Psup (at Tdesign -10°C)	kW	2.2	2.4	3.2	4.1
		Tbiv (bivalent temperature)	COPd		1.92	1.90	2.09	2.13
			Pdh	kW	8.8	9.3	9.4	10.1
			PERd	%	76.8	76.0	83.6	85.2
			Tbiv	°C	-8	-7	-6	-5
	Cold climate water outlet 55°C	General	Annual energy consumption	kWh	7,376	8,196	8,808	9,599
			ηs (Seasonal space heating efficiency)	%	117		120	
			Prated at -22°C	kW	9.0	10.0	11.0	12.0
			Qhe Annual energy consumption (GCV)	Gj	27	30	32	35
	Warm climate water outlet 55°C	General	Annual energy consumption	kWh	2,820	3,083	3,690	
			ηs (Seasonal space heating efficiency)	%	168	170	172	
			Prated at 2°C	kW	9.0	10.0	12.1	
			Qhe Annual energy consumption (GCV)	Gj	10	11	13	
		B Condition (2°CDB/1°CWB)	Cdh (Degradation heating)		1.0			
			COPd		2.12	2.18	2.17	
			Pdh	kW	9.0	9.8		
			PERd	%	84.8	87.2	86.8	
		C Condition (7°CDB/6°CWB)	Cdh (Degradation heating)		1.0			
			COPd		3.65	3.74	3.83	
			Pdh	kW	6.2		7.6	
			PERd	%	146.0	149.6	153.2	
		D Condition (12°CDB/11°CWB)	Cdh (Degradation heating)		1.0			
			COPd		5.68		5.69	
			Pdh	kW	5.0			
			PERd	%	227.2		227.6	
		Tbiv (bivalent temperature)	COPd		2.12	2.18	2.40	
			Pdh	kW	9.0	9.8	11.0	
			PERd	%	84.8	87.2	96.0	
			Tbiv	°C	2		3	
	Average climate water outlet 35°C	General	Annual energy consumption	kWh	3,854	4,371	4,838	5,281
			ηs (Seasonal space heating efficiency)	%	190	186	185	
			Prated at -10°C	kW	9.0	10.0	11.0	12.0
			Qhe Annual energy consumption (GCV)	Gj	14	16	17	19
			SCOP		4.82	4.73	4.70	4.69
			Seasonal space heating eff. class		A+++			
		A Condition (-7°CDB/-8°CWB)	COPd		3.07	3.03	2.95	2.87
			Pdh	kW	8.5	9.2	10.1	11.2

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Technical specifications					EBLA09D3V3	EBLA11D3V3	EBLA14D3V3	EBLA16D3V3
Space heating	Average climate water outlet 35°C	A Condition (-7°CDB/-8°CWB)	PERd	%	122.8	121.2	118.0	114.8
		B Condition (2°CDB/1°CWB)	Cdh (Degradation heating)		1.0			
			COPd		4.52	4.37	4.35	4.33
			Pdh	kW	5.5		6.1	6.7
			PERd	%	180.8	174.8	174.0	173.2
		C Condition (7°CDB/6°CWB)	Cdh (Degradation heating)		1.0			
			COPd		6.78	6.74	6.70	6.83
			Pdh	kW	4.7	4.6		4.7
			PERd	%	271.2	269.6	268.0	273.2
		D Condition (12°CDB/11°CWB)	Cdh (Degradation heating)		1.0			
			COPd		8.75	8.54	8.65	8.82
			Pdh	kW	5.5	5.4		5.5
			PERd	%	350.0	341.6	346.0	352.8
		Tol (temperature operating limit)	COPd		2.64	2.58	2.51	2.48
			Pdh	kW	8.3	10.1	11.2	11.8
			PERd	%	105.6	103.2	100.4	99.2
			TOL	°C	-10			
			WTOL	°C	35			
		Tbiv (bivalent temperature)	COPd		2.75	2.58	2.51	2.48
			Pdh	kW	8.7	10.1	11.2	11.8
			PERd	%	110.0	103.2	100.4	99.2
			Tbiv	°C	-9	-10		
		Rated heat output supplementary capacity	Psup (at Tdesign -10°C)	kW	0.7	0.0		
	Cold climate water outlet 35°C	General	Annual energy consumption	kWh	5,351	5,732	6,266	7,245
			ηs (Seasonal space heating efficiency)	%	163	169	170	160
			Prated at -22°C	kW	9.0	10.0	11.0	12.0
			Qhe Annual energy consumption (GCV)	Gj	19	21	23	26
	Warm climate water outlet 35°C	General	Annual energy consumption	kWh	1,938	2,128	2,333	2,573
			ηs (Seasonal space heating efficiency)	%	243	248	249	246
			Prated at 2°C	kW	9.0	10.0	11.0	12.0
			Qhe Annual energy consumption (GCV)	Gj	7	8		9
		B Condition (2°CDB/1°CWB)	Cdh (Degradation heating)		1.0			
			COPd		3.36	3.30	3.45	3.30
			Pdh	kW	9.0	10.3	10.8	11.9
			PERd	%	134.4	132.0	138.0	132.0
		C Condition	Cdh (Degradation heating)		1.0			
			COPd		5.59	5.70	5.77	5.64
Space heating	Warm climate water outlet 35°C	C Condition (7°CDB/6°CWB)	Pdh	kW	5.9	6.7	7.4	8.1
			PERd	%	223.6	228.0	230.8	225.6
		D Condition (12°CDB/11°CWB)	Cdh (Degradation heating)		1.0			
			COPd		7.87		7.73	
			Pdh	kW	5.2			
			PERd	%	314.8		309.2	
		Tbiv (bivalent temperature)	COPd		3.36	3.30	3.45	3.30
			Pdh	kW	9.0	10.3	10.8	11.9
			PERd	%	134.4	132.0	138.0	132.0
			Tbiv	°C	2			
Control systems	Class of temperature control				VI			
	Contribution to seasonal space heating efficiency			%	4			

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Electrical specifications					EBLA09D3V3 / EBLA11D3V3 / EBLA14D3V3 / EBLA16D3V3
Compressor	Starting method				Inverter
Pump	Type				PWM
Compressor component	Main power supply	Phase			1~
		Voltage		V	230
	Voltage range	Min.		%	-10
		Max.		%	10
Hydraulic component	Back-up heater current	Type			3V3
		Power supply	Phase		1~
			Frequency	Hz	50
			Voltage	V	230
		Running current	Back-up heater	A	13.0
	Voltage range	Min.		%	-10
		Max.		%	10
	Wiring connections	Type of wires			Select diameter and type according to national and local regulations
Power supply	Name				V3
	Phase				1~
	Frequency			Hz	50
	Voltage			V	230
Voltage range	Min.			%	-10
	Max.			%	10
Current	Maximum running current	Heating		A	30.8
	Recommended fuses			A	32
Wiring connections	Optional domestic hot water tank + Q2L	Quantity			3G
		Type of wires			Minimum 2.5 mm²
	R5T	Quantity			2
		Type of wires			Wire included in option EKHWS*
	For connection with R6T	Quantity			2
		Remark			Minimum 0.75 mm²
	A3P	Quantity			4
		Type of wires			Select diameter and type according to national and local regulations
	M2S	Quantity			2
		Type of wires			Select diameter and type according to national and local regulations
	M3S	Quantity			3
		Type of wires			Select diameter and type according to national and local regulations
	Quantity				2
	Type of wires				Wire included in option EKFLSW1
Wiring connections	For power supply	Quantity			2G
		Remark			See installation manual outdoor unit
	For connection with user interface	Quantity			4
		Remark			0.75 mm² till 1.25 mm² (max length 200 m)
		Type of wires			0,75 ~1,25 mm² (P1P2)
	Preferential kWh rate power supply	Quantity			Power: 2
		Remark			Power 6.3A
	Domestic hot water pump	Quantity			3
		Remark			Minimum 0.75 mm²
Cable requirements	Cooling/Heating output	Maximum running current		A	0.3

(1)Condition: Ta DB/WB 7°C/6°C - LWC 35°C (DT = 5°C) |
(2)Condition: Ta DB/WB 7°C/6°C - LWC 45°C (Dt=5°C) |
(3)Cooling: EW 12°C; LW 7°C; ambient conditions: 35°CDB |
(4)Cooling: EW 23°C; LW 18°C; ambient conditions: 35°CDB |
(5)According to EN14825 |
(6)For more details, see operation range drawing |
(7)Depends on operation mode, refer to installation manual.

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6.3.2 *Czech demonstration heat pump (DAIKIN) specifications*

Technical specifications					EBBH11D6V + ERLA11DW1	EBBH16D6V + ERLA14DW1	EBBH16D6V + ERLA16DW1
Heating capacity	Nom.			kW	10.6 (1) / 9.82 (2)	12.0 (1) / 12.5 (2)	16.0 (1) / 16.0 (2)
Power input	Heating	Nom.		kW	2.18 (1) / 2.68 (2)	2.46 (1) / 3.42 (2)	3.53 (1) / 4.56 (2)
COP					4.83 (1) / 3.66 (2)	4.87 (1) / 3.64 (2)	4.53 (1) / 3.51 (2)
Pump	Nominal ESP unit	Heating		kPa	46.2 (3) / 47.7 (4)	62.8 (3) / 59.5 (4)	31.3 (3) / 31.3 (4)
Water side Heat exchanger	Water flow rate	Heating	Nom.	l/min	29.3 (3) / 28.7 (4)	34.7 (3) / 36.1 (4)	46.1 (3) / 46.1 (4)
General	Supplier/ Manufacturer details	Name and address			Daikin Europe N.V. - Zandvoordestraat 300, 8400 Oostende, Belgium		
		Name or trademark			Daikin Europe N.V.		
	Product description	Air-to-water heat pump			Yes		
		Brine-to-water heat pump			No		
		Heat pump combination heater			No		
		Low-temperature heat pump			No		
		Supplementary heater integrated			Yes		
		Water-to-water heat pump			No		
	LW(A) Sound power level (according to EN14825)	Indoor		dB(A)	44.0 (5)		
LW(A) Sound power level (according to EN14825)	Outdoor			dB(A)	62.0		
Sound condition Ecodesign and energy label					Sound power in heating mode, measured according to the EN12102 under conditions of the EN14825		
Space heating general	Air to water unit	Rated airflow (outdoor)		m^3/h	3,350	4,220	5,100
	Other	Capacity control			Inverter		
		Pck (Crankcase heater mode)		kW	0.000		
		Poff (Off mode)		kW	0.023		
		Psb (Standby mode)		kW	0.023		
		Pto (Thermostat off)		kW	0.023		
	Integrated supplementary heater	Psup		kW	6.0		
		Type of energy input			Electrical		
Space heating	Average climate water outlet 55°C	General	Annual energy consumption	kWh	6,397	7,047	7,477
			ηs (Seasonal space heating efficiency)	%	126		130
			Prated at -10°C	kW	10	11	12
			Qhe Annual energy consumption (GCV)	Gj	23	25	27
			SCOP		3.23	3.22	3.32
			Seasonal space heating eff. class		A++		
		A Condition (-7°CDB/-8°CWB)	Cdh (Degradation heating)		1.0		
			COPd		1.89	1.80	1.95
			Pdh	kW	7.9	8.5	9.4
			PERd	%	75.6	72.0	78.0
		B Condition (2°CDB/1°CWB)	Cdh (Degradation heating)		1.0		
			COPd		3.25	3.28	3.27

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Technical specifications					EBBH11D6V + ERLA11DW1	EBBH16D6V + ERLA14DW1	EBBH16D6V + ERLA16DW1
Space heating	Average climate water outlet 55°C	B Condition (2°CD-B/1°CWB)	Pdh	kW	5.4	6.2	6.9
			PERd	%	130.0	131.2	130.8
		C Condition (7°CD-B/6°CWB)	Cdh (Degradation heating)		1.0		
			COPd		4.81	4.88	4.93
			Pdh	kW	4.4		
			PERd	%	192.4	195.2	197.2
		D Condition (12°CDB/11°CWB)	Cdh (Degradation heating)		1.0		
			COPd		6.41	6.58	6.60
			Pdh	kW	5.3		
			PERd	%	256.4	263.2	264.0
		Tol (temperature operating limit)	COPd		1.68	1.76	1.50
			Pdh	kW	6.8	7.0	6.0
			PERd	%	67.2	70.4	60.0
			TOL	°C	-10		
			WTOL	°C	55		
		Rated heat output supplementary capacity	Psup (at Tdesign -10°C)	kW	3.2	4.0	6.1
		Tbiv (bivalent temperature)	COPd		1.96	1.87	2.13
			Pdh	kW	8.2	8.9	10.1
			PERd	%	78.4	74.8	85.2
			Tbiv	°C	-5		
	Cold climate water outlet 55°C	General	Annual energy consumption	kWh	8,082	9,024	9,561
			ηs (Seasonal space heating efficiency)	%	119	117	121
			Prated at -22°C	kW	10	11	12
			Qhe Annual energy consumption (GCV)	Gj	29	32	34
	Warm climate water outlet 55°C	General	Annual energy consumption	kWh	3,258	3,818	3,792
			ηs (Seasonal space heating efficiency)	%	161	166	168
			Prated at 2°C	kW	10	12.1	
			Qhe Annual energy consumption (GCV)	Gj	12	14	
		B Condition (2°CD-B/1°CWB)	Cdh (Degradation heating)		1.0		
			COPd		2.24	2.20	2.17
			Pdh	kW	9.0	10.1	9.8
			PERd	%	89.6	88.0	86.8
		C Condition (7°CD-B/6°CWB)	Cdh (Degradation heating)		1.0		
			COPd		3.74	3.83	
			Pdh	kW	6.2	7.6	
			PERd	%	149.6	153.2	
		D Condition (12°CDB/11°CWB)	Cdh (Degradation heating)		1.0		

Technical specifications					EBBH11D6V + ERLA11DW1	EBBH16D6V + ERLA14DW1	EBBH16D6V + ERLA16DW1
Space heating	Warm climate water outlet 55°C	D Condition (12°CDB/11°CWB)	COPd		5.68	5.69	
			Pdh	kW	5.0		
			PERd	%	227.2	227.6	
		Tbiv (bivalent temperature)	COPd		2.41	2.65	2.40
			Pdh	kW	8.5	11.1	11.0
			PERd	%	96.4	106.0	96.0
			Tbiv	°C	4		3
	Average climate water outlet 35°C	General	Annual energy consumption	kWh	4,462	4,935	5,377
			ηs (Seasonal space heating efficiency)	%	182	181	
			Prated at -10°C	kW	10	11	12
			Qhe Annual energy consumption (GCV)	Gj	16	18	19
			SCOP		4.63	4.60	4.61
			Seasonal space heating eff. class		A+++		
		A Condition (-7°CDB/-8°CWB)	COPd		3.03	2.99	2.87
			Pdh	kW	9.2	9.8	11.2
			PERd	%	121.2	119.6	114.8
		B Condition (2°CDB/1°CWB)	Cdh (Degradation heating)		1.0		
			COPd		4.37	4.35	4.33
			Pdh	kW	5.5	6.1	6.7
			PERd	%	174.8	174.0	173.2
		C Condition (7°CDB/6°CWB)	Cdh (Degradation heating)		1.0		
			COPd		6.74	6.70	6.83
			Pdh	kW	4.6		4.7
			PERd	%	269.6	268.0	273.2
		D Condition (12°CDB/11°CWB)	Cdh (Degradation heating)		1.0		
			COPd		8.54	8.65	8.82
			Pdh	kW	5.4		5.5
			PERd	%	341.6	346.0	352.8
		Tol (temperature operating limit)	COPd		2.73	2.71	2.52
			Pdh	kW	8.4	9.1	10.6
			PERd	%	109.2	108.4	100.8
			TOL	°C	-10		
			WTOL	°C	35		
		Tbiv (bivalent temperature)	COPd		3.01	2.99	2.72
			Pdh	kW	9.2	9.8	11.4
			PERd	%	120.4	119.6	108.8
			Tbiv	°C	-8	-7	-8

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Technical specifications					EBBH11D6V + ERLA11DW1	EBBH16D6V + ERLA14DW1	EBBH16D6V + ERLA16DW1
Space heating	Average climate water outlet 35°C	Rated heat output supple-mentary capacity	Psup (at Tdesign -10°C)	kW	1.6	1.9	1.4
	Cold climate water outlet 35°C	General	Annual energy consumption	kWh	5,951	6,439	7,257
			ηs (Seasonal space heating efficiency)	%	163	165	160
			Prated at -22°C	kW	10	11	12
			Qhe Annual ener-gy consumption (GCV)	Gj	21	23	26
	Warm climate water outlet 35°C	General	Annual energy consumption	kWh	2,228	2,431	2,675
			ηs (Seasonal space heating efficiency)	%	236	239	237
			Prated at 2°C	kW	10	11	12
			Qhe Annual ener-gy consumption (GCV)	Gj	8	9	10
		B Con-dition (2°CD-B/1°CWB)	Cdh (Degradation heating)			1.0	
			COPd		3.64	3.51	3.30
			Pdh	kW	9.8	11.0	11.9
			PERd	%	145.6	140.4	132.0
		C Con-dition (7°CD-B/6°CWB)	Cdh (Degradation heating)			1.0	
			COPd		5.70	5.77	5.64
			Pdh	kW	6.7	7.4	8.1
			PERd	%	228.0	230.8	225.6
		Tbiv (bivalent tempera-ture)	COPd		3.81	3.51	3.30
			Pdh	kW	9.2	11.0	11.9
			PERd	%	152.4	140.4	132.0
			Tbiv	°C	3	2	
		D Condition (12°CDB/11°CWB)	Cdh (Degradation heating)			1.0	
			COPd		7.87	7.73	
			Pdh	kW		5.2	
			PERd	%	314.8	309.2	

(1)Condition: Ta DB/WB 7°C/6°C - LWC 35°C (DT = 5°C) |
(2)Condition: Ta DB/WB 7°C/6°C - LWC 45°C (Dt=5°C) |
(3)Condition 1: cooling Ta 35°C - LWE 18°C (DT = 5°C); heating Ta DB/WB 7°C/6°C - LWC 35°C (DT = 5°C) |
(4)Condition 2: cooling Ta 35°C - LWE 7°C (DT = 5°C); heating Ta DB/WB 7°C/6°C - LWC 45°C (DT = 5°C) |
(5)Measured with a pressure drop of 10 kPa in the heating system at an operating condition of leaving water 47-55°C in a room with an ambient of 20°C. DB/WB 7°C/6°. |
Cooling: EW 12°C; LW 7°C; ambient conditions: 35°CDB |
Cooling: EW 23°C; LW 18°C; ambient conditions: 35°CDB |
According to EN14825

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